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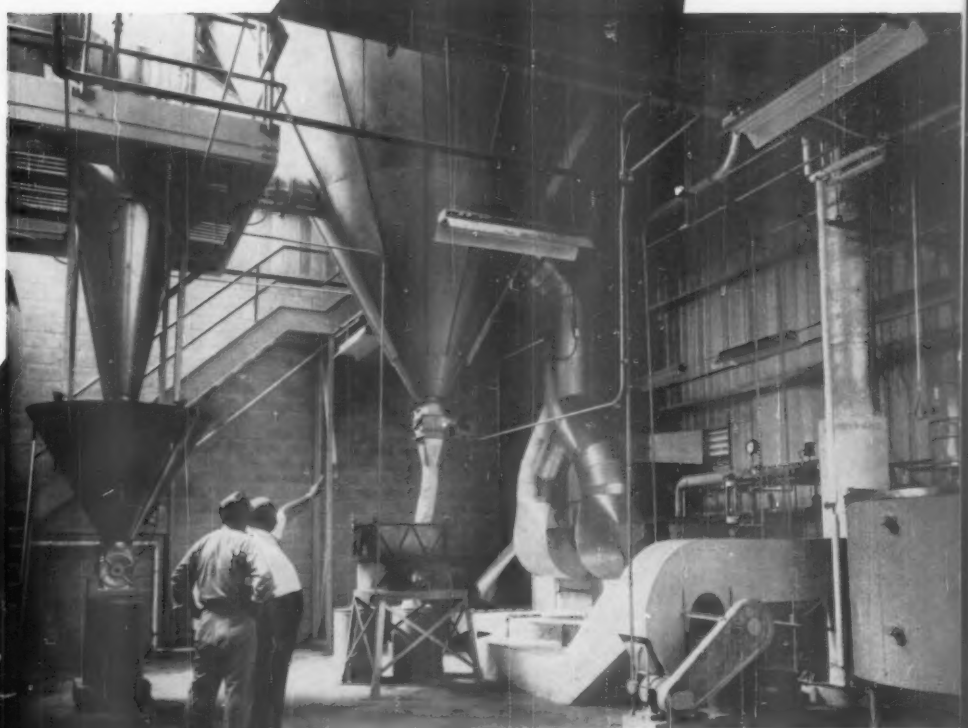
FT food technology



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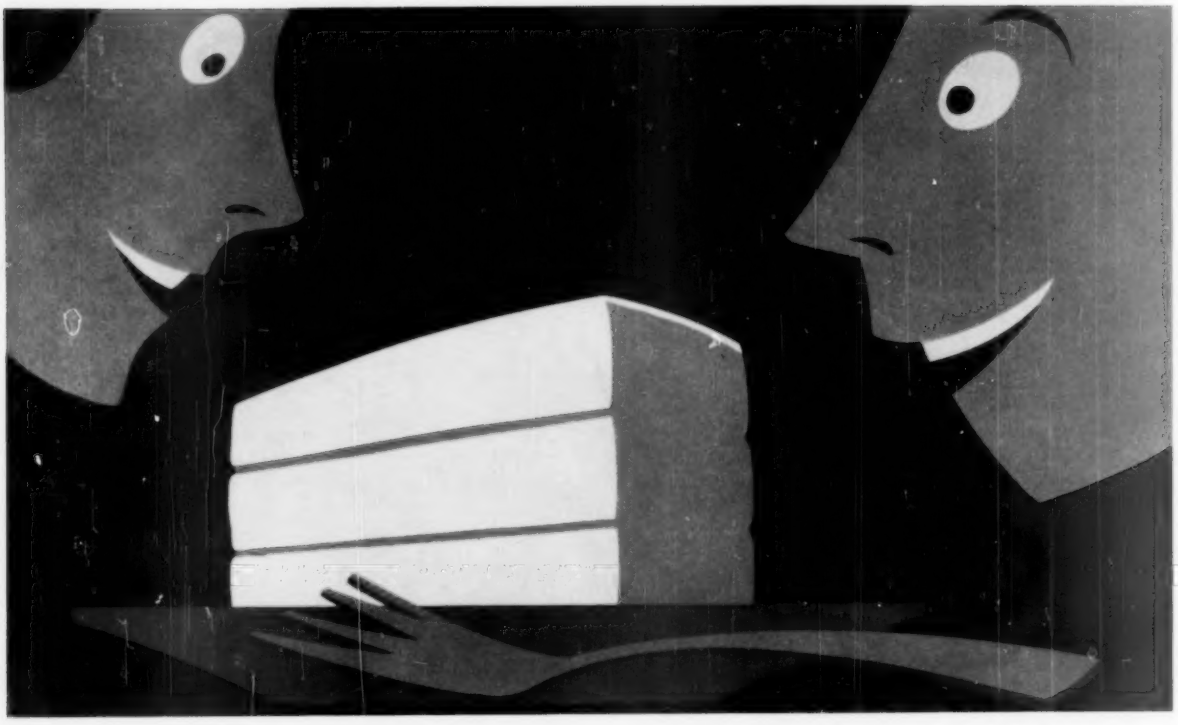

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Aluminum Foil Packaging-Expansion of Research Facilities

Report No. 13 of a Series by Reynolds Metals Company

REPORT NO. 1 of this series detailed the research staff and the laboratory facilities which provide basic data for these reports. The ever-widening acceptance of aluminum foil materials and the continually expanding range of products being packaged in these materials have, of course, necessitated considerable additions to the laboratory. Now, as the series embarks on its third year, it is important once again to familiarize the reader with the expanded staff and facilities responsible for these technical reports.

Primarily, the basic purposes of this laboratory are: continual evaluation and improvement of performance and economy of currently used aluminum foil packaging materials; investigation and development of all materials used in conjunction with foil (papers, adhesives, inks, coatings, waxes, hot melts, plastic films, etc.); and exploration and invention in entirely new areas of flexible, semi-rigid and rigid packaging with aluminum. This includes the development of associated production type machinery.

Operate Pilot Plant

In order to fulfill these aims, Reynolds maintains not only the packaging laboratory, but also a fully integrated pilot plant for the development and production of aluminum packaging materials. Since the actual use of a product provides still another testing ground for the packaging of new products or the adaptation of existing equipment to aluminum foil materials, technical services rendered right in customers' plants have become yet another important area covered by the Research and Development Department. This technical assistance is available through Reynolds regional representatives.

Newly acquired package testing equipment in the laboratory includes walk-in temperature cabinets, a combination plate and blast freezer, and several different types of in-store display refrigerators and freezers. This is in addition to the spectrophotometer, complete photographic equipment and laboratories, vibration testing machinery, Atlas fadeometer, temperature, humidity and moisture vapor transmission cabinets, and various other paper, film and foil testing apparatus which were detailed in Report No. 1. The laboratory also maintains a test kitchen completely equipped with both gas and electric appliances.

The pilot plant, now housed in an entirely new building, has been expanded with the addition of a 4-color gravure printing press, a plastics extruder and laminator, and new equipment for coating, laminating and spooling foil. Also available are bag making machinery, several different types of heat sealers and other package making equipment which was described in Report No. 1.

The increasing rate of technological advance in several diverse fields of aluminum foil packaging, as well as the enlarged scope of the Department itself, has necessitated a 50% increase in the number of scientists and technicians on the staff.

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Over-all expansion and integration of the laboratory and pilot plant facilities—the world's most extensive 2 years ago and larger than ever today—result in the following benefits to Reynolds and to Reynolds customers:

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The past discoveries of this laboratory have been significant—among them new data relating the properties of aluminum foil to vacuum packaging, heat conductivity and reflectivity, vitamin and flavor retention, antioxidants, bacteriology, and other highly specialized fields. These discoveries will continue to be reported in this series.

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No. 1 Research and Development Laboratories for Aluminum Foil Packaging
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No. 3 Aluminum Foil Packaging as a Gas Barrier
No. 4 Aluminum Foil Packaging as a Grease and Oil Barrier
No. 5 Aluminum Foil Packaging as an Insulator
No. 6 Aluminum Foil Packaging as a Light Barrier
No. 7 Aluminum Foil Packaging as Protection Against Contamination
No. 8 Aluminum Foil Packaging—Versatility and Compatibility Unexcelled
No. 9 Aluminum Foil Packaging—Advantages of High Thermal Conductivity
No. 10 Aluminum Foil Packaging—Resistance to Insect Infestation
No. 11 Aluminum Foil Packaging—Resistance to Heat and Flame
No. 12 Aluminum Foil Packaging as a Material for Printing

A limited number of these reports is still available. Write for copies you may wish, specifying Report Number.

Watch Reynolds all-family television show "Disneyland", ABC-TV.

IN THIS ISSUE—

THE TECHNICAL ARTICLES IN BRIEF

Packaging *Prepackaged meat*

Factors affecting the quality of prepackaged meat. II. E. Development of a method for determining the proportions of heme derivatives in meat. Hormoz Broumand, C. Olin Ball, and Elizabeth F. Stier.

This study describes the development of a method, called the "absorbancy ratio method," for application to heme derivatives. A consistent relationship is shown between results obtained by the absorbancy ratio method and color manifestations that occur in connection with chemical changes in meat pigments. (See page 65.)

Waste disposal *Dairy waste*

Application of laboratory studies to practical dairy waste disposal. Nandor Porges.

Pollution effect of a food waste is a measure of the oxygen required for its stabilization. Dairy waste is considered a strong waste, difficult to treat. However, laboratory studies show that by satisfying basic oxygen requirements this waste can be treated by aeration. Conversion of organic solubles to insoluble and harmless material is a biological process carried out by microorganisms. Complete combustion of 1 lb. of organic matter requires 1.2 lb. oxygen. Conversion to bacterial cells requires only 0.45 lb. of oxygen that must be supplied at high rates depending on the concentration of the seed bacteria. About half of the organic matter is dissipated while half is found as cell substance. The remaining 0.75 lb. of oxygen demand is used slowly by the cells during endogenous respiration. Equations showing these changes and data derived from laboratory studies are presented. This information was applied to studies in a 10,000 gallon pilot plant at Pennsylvania State University. Designs were developed for treating dairy waste by a fill-and-draw one-tank procedure and by a continuous flow method and are described. These are less costly than conventional methods and are now in practical use at a number of dairies. Means of treating food wastes are suggested by these laboratory and pilot plant studies. (See page 78.)

Grading *Canned cling peaches*

Factors influencing drained weight of canned cling peaches. S. J. Leonard, B. S. Luh, and E. M. Mrak.

Drained weight and Brix readings are important factors in grading canned cling peaches. Immediately after the peaches are canned, the drained weight falls below the filling weight because fluid from peach tissue is lost to the sugar syrup as a result of osmosis. On storage, the weight of peach tissue increases again because of penetration of sugar into the fruit. Drained weight decreased with increase in concentration of the ingoing sucrose syrup. Equilibrium Brix readings increased with increase in concentration of the ingoing syrup. For dietetic canned peaches which were canned in plain water, the drained weight was higher than for those canned in sucrose syrup. The influence of fill weight, maturity of fruit, concentration of ingoing sucrose syrup, and storage time on drained weight and on Brix reading of canned cling peaches is presented. (See page 80.)

Aging *Beef*

Shrinkage and organoleptic characteristics of beef aged in controlled environments. R. B. Sleeth, G. G. Kelley, and D. E. Brady.

The effect of various temperature, humidity, air flow, and ultraviolet radiation conditions has been studied on paired beef quarters and wholesale cuts of different weights and grades. Determinations were made of shrinkage, color, drip loss, and cooking loss; organoleptic responses reflecting the differential effects of the various aging treatments were studied. Effect of the different treatments on sensory values of rib and round steaks after 2, 4, 8, and 12 months' storage at 0° F. has been ascertained. A method of predicting shrinkage and organoleptic characteristics of beef aged under controlled environmental conditions is presented. (See page 86.)

Cooking quality *New durum wheats*

The cooking properties of some new durum wheat varieties. R. H. Harris and L. D. Sibbitt.

Macaroni made from 126 samples of durum wheat grown in experimental plots at North Dakota stations in 1954, 1955 and 1956 was evaluated for cooking quality. Principal quality properties measured were cooked weight, degree of disintegration, and tenderness score. From this investigation it seems that macaroni toughness, as indicated by tenderness score, increases with protein content.

February Cover. Preserving foods by dehydration is an ancient art but the solution of production and product problems has had to await modern technology and engineering. The spray dryer pictured on the cover (courtesy, Polak and Schwarz) represents one method of drying by heat. A nozzle delivers the food material into a chamber fed continuously by a blast of hot air.

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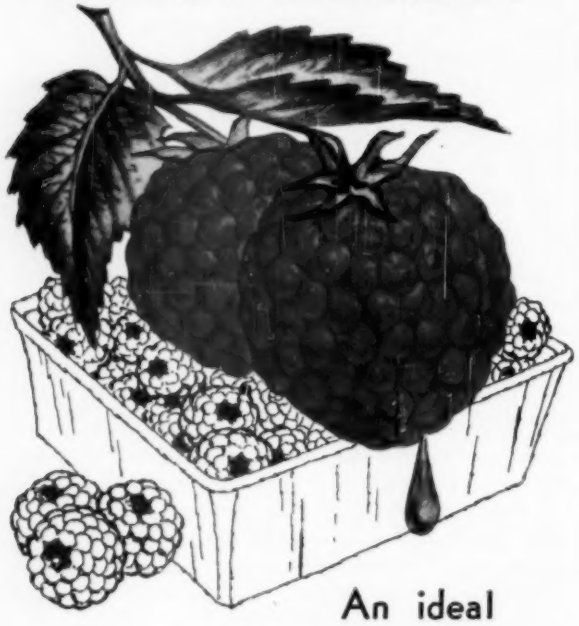

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There were marked differences between durum wheat varieties in dough mixing requirements. Variations in tenderness score were also marked but smaller than for mixing requirements. As expected, semolina protein content was very significantly affected by wheat variety, location of growth, and year of growth. Of these, location of growth had the most pronounced effect, and year of growth the least. For cooked weight, variety alone exerted a significant influence; for residue, variety was without effect, years having the largest influence. For tenderness score, location and year of growth had approximately equal effects, while variety was less influential. (See page 91.)

Scald formation *Montmoreney cherries*

Causes of scald in red tart cherries. R. L. LaBelle, J. C. Moyer, W. B. Robinson, and D. B. Hand.

Processing variables which affect the incidence of scald occurring in Montmoreney cherries have been studied. It has been shown that the damage from scald and oxidation in frozen or canned red tart pitted cherries results largely from careless handling of the fruit before processing. Excessive bruising and prolonged holding at high ambient temperatures are the chief causes. Soaking cherries in cold water slows, but by no means halts, the development of scald. (See page 94.)

Canning technology *Blueberries*

Clumping in canned blueberries. M. J. Powers, R. M. Reeve, L. R. Leinbach, W. F. Talburt, and J. E. Brekke.

Canned blueberries may vary from a highly attractive, free-flowing product to one that is clumped into a firm mass. Severely clumped berries are less desirable, more difficult to use, and separation often results in torn skins and unattractive pulp. The tendency of some varieties to clump when canned was studied by canning trials and by chemical and histological observations. Clumping can be greatly reduced by cooling under agitation, which apparently interferes with the binding together of berries by surface wax or cutin. (See page 99.)

Scald formation *Red tart cherries*

Studies on cherry scald. I. Relationship between bruising and respiration in water. Robert L. Pollack, C. Ricciuti, C. F. Woodward, and Claude H. Hills.

A study was made of the oxygen consumption of red tart cherries while submerged in water at 10° and 30° C. It was observed that both an elevation in temperature and bruising increased the respiratory rate. Calculation of the kinetic data for the respiratory rate of bruised cherries resulted in pseudo first order plots, showing that the rate-determining factor was the concentration of dissolved oxygen. Scald formation was observed with bruised cherries at low oxygen concentrations. At 10° C. bruised cherries scalded when the oxygen level fell below 3 p.p.m. At 30° C., however, bruised cherries scalded even in fully

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aerated water. Unbruised cherries at these same low oxygen concentrations did not scald, which indicates that bruising and the consequent disruption of the normal respiratory system is the primary factor in scald formation. (See page 102.)

Scald formation *Red tart cherries*

Studies on cherry scald. II. Relationship between bruising and respiration in air. Robert L. Pollack, R. T. Whittenberger, and Claude H. Hills.

Unbruised red tart cherries respiring in air gave a respiratory quotient of 0.9 at 10° C. and of 1.0 at 30° C. Raising the temperature from 10° to 30° C. caused nearly a threefold increase in oxygen consumption of unbruised fruit. Under conditions of stress such as bruising, oxygen consumption and carbon dioxide evolution rose at either temperature. Bruised cherries stored in air at 90° F. for only 2 hours scalded at the points of contact between cherries, and between cherries and container. Scald development was correlated with extent of bruising and with length of the delay period after bruising. (See page 106.)

Antibiotics *Fish*

Comparative effectiveness of tetracycline antibiotics for fish preservation. J. W. Boyd, B. A. Southcott, E. G. Baker, and H. L. A. Tarr.

Previous work, which was based largely on differences obtained in storing ground fish samples in which antibiotics were incorporated, indicated that chlortetracycline (CTC) was more effective than oxytetracycline (OTC) or tetracycline (TC) in retarding bacterial spoilage. The comparative effectiveness of these 3 antibiotics has now been assessed, using different species of fish and the following practical methods of application: (1) Incorporation of 5 p.p.m. of the antibiotic in the ice used for icing fish; (2) addition of 1-2 p.p.m. in chilled 3% salt solution used for holding eviscerated fish; and (3) addition of 5 p.p.m. to solutions used for dipping fillets. The results showed that CTC was more effective than the other two tetracyclines in retarding bacterial spoilage of treated fish. (See page 108.)

Sugar penetration *Canned cling peaches*

Penetration of maltosaccharides in processed clingstone peaches. R. E. Hughes, Jr., C. O. Chichester, and Clarence Sterling.

Sugar penetration into canned clingstone peaches was investigated using C^{14} labeled starch hydrolysis products of the amylose series. Small amounts of the C^{14} labeled sugars ranging in size from glucose to maltohexose were added to a normal cover syrup in which the clingstone peaches were canned. Normal canning procedures were followed. The penetration of the individual sugar into the processed peaches was studied by the use of histological and radiochemical techniques. (See page 111.)

FUTURE MEETINGS FOR FOOD TECHNOLOGISTS

February 14–16	Institute of American Poultry Industries 1958 Fact Finding Conference, Municipal Auditorium, Kansas City, Missouri
February 25–26	Sixth Annual National Dairy Engineering Conference, Kellogg Center, Michigan State University, East Lansing, Michigan
March 2–6	Convention of National Association of Frozen Food Packers and Exposition, Conrad Hilton Hotel, Chicago
March 2–9	International Trade Fair of Packaging Machines, Confectionery Machines and Packaging Materials, Dusseldorf, Germany
March 6–8	Annual Meeting of the Refrigeration Research Foundation, Adolphus Hotel, Dallas, Texas
March 14–15	Annual Food Technology Symposium and Short Course, University of Missouri, Columbia, co-sponsored by the St. Louis and the Kansas City Sections of IFT
April 7–11	The American Association of Cereal Chemists, Netherland-Hilton Hotel, Cincinnati, Ohio
April 22–24	Research and Development Associates of the Food and Container Institute, Palmer House, Chicago
May 25–29	**Eighteenth Annual Meeting of the Institute of Food Technologists, Palmer House, Chicago, Illinois**

1959	
May 17–21	**Nineteenth Annual Meeting of the Institute of Food Technologists, Bellevue-Stratford Hotel, Philadelphia, Pennsylvania**
1960	
May 15–19	**Twentieth Annual Meeting of the Institute of Food Technologists, Civic Auditorium and Hotel Whitcomb, San Francisco, California**
1961	
May 7–11	**Twenty-first Annual Meeting of the Institute of Food Technologists, Hotel Statler, New York, New York**
1962	
June 17–20	**Twenty-second Annual Meeting of the Institute of Food Technologists, Americana Hotel, Bal Harbor, Miami Beach, Florida**

June 8–12	Inter American Food Congress, Americana Hotel, Bal Harbor, Miami Beach, Florida. For information address J. Arthur Lewis, Box 954, South Miami 43, Florida
June 10–13	First International Congress on Vacuum Techniques, Namur, Belgium
June 12–13	First National Convention, Canadian Institute of Food Technology, Queen Elizabeth Hotel, Montreal. Theme: Canada's Food Industries

An open invitation is extended to readers of FOOD TECHNOLOGY to send in to the Editorial Office, 11606 South Bell Avenue, Chicago 43, Illinois notices of annual or national meetings of interest to food technologists.

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The Education of a Food Technologist

Norman W. Desrosier[a]
Purdue University, Lafayette, Indiana

LET US DEFINE the smallest unit of information to be a "bit". Then knowledge can be defined as the sum of these bits. A science is a branch of knowledge embracing a body of organized, useful bits of information of the material world. We can then say that there is a science which deals with the foods of man. This branch of learning we call Food Technology.

Man's foods come from plants and animals and a continuous supply is basic to his existence. All of man's foods are perishable commodities; they begin to deteriorate shortly after harvest, gather, or slaughter. Some deterioration is accompanied by the production of poisonous agents; other deterioration inflicts losses in the nutritive value of food. Man has learned to control some of the natural destructive forces and withhold the fruits of nature as his food supply. Toward this end, mankind has accumulated a technology. This technology was instrumental in the civilization of man, and has played no small part in the spread of civilization.

Nature has secrets to unfold before inquiring minds. Billions of inquiring minds reveal truths at a snail's pace, if the method of inquiry is unorganized. In recent centuries a method of inquiry has been revealed—the scientific method. It is based upon the reproducibility of the results of experimentation, and the results are cumulative. This method in the past few centuries equals that learned by all mankind in the past thousands of centuries without it.

Knowledge of man's foods is founded in the physical and biological sciences. The inter-relationships are not sidelights, but the technology itself. For this reason, food technology offers opportunities for the integration of knowledge for the betterment of mankind, and therefore offers great challenge to students, young or old.

If food technology is such a useful area for mankind, how can we develop new information in this important field? We must seek it. How do we seek new knowledge? Through educated minds. The secret weapon in progress is this educated mind. The problem, now identified, is how can we educate students to seek new information of man's food.

Scientist, Technologist, and Technician

A scientist is one who contributes to the stream of organized information. A technologist is one who is versed in and applies this information to a field of endeavor. A technician need not be versed in the knowledge of the science but applies the information for the betterment of society. The desirable ratio of scientist to technologist to technician for the most rapid progress of society is not clearly established, although some order is apparent.

A Food Scientist is one who contributes to the knowledge of man's food. Knowledge of man's food involves physical, chemical, mathematical, and biological information. A Food Technologist is one versed in these bodies of information. A Food Technologist by this definition may or may not be a scientist.

Technologists from a multitude of disciplines of learning are essential for the wheels of civilization to turn. The integration of science and technology contributes to the advancement of mankind, which we seek.

Food Technology—Education vs. Training

The training of Food Technologists and Food Scientists is therefore clearly indicated as an interdisciplinary activity in the physical, chemical, mathematical and biological fields. The education of the student on the other hand immediately embraces not only the sciences but the humanities as well.

Knowledge in the physical and biological sciences is cumulative knowledge. Valid generalizations in the natural sciences depend upon wide experiences and reproducibility. The knowledge of the humanities is generally considered non-cumulative knowledge. Knowledge of the social and political behavior of man is perhaps cumulative but little progress has been made, so little apparently, that it appears non-cumulative. Art and music are examples of non-cumulative knowledge.

The educational process then must be a concerted effort in both cumulative and non-cumulative knowledge. The goal is the production of a whole man, with information not only of the physical and biological processes of the material world he exists in, but of man the being as well.

In this day and age, the educational processes are established in our society. Technicians are produced at the high school level of learning. Technologists are the products of the technical undergraduate schools of the universities. Scientists are the products of the graduate schools of the universities. These programs are formal training programs. At any level in the educational scheme, options are available which direct the student towards the best utilization of his faculties. One of the ultimate rewards to the individual relates to the proper utilization of his talents.

The difficulty involved in mass education at all levels in the educational scheme relates to the treatment of students as groups. The resulting channels the students fall within are in many instances exasperating. Nonetheless, the benefits from the system

[a] Present address: Radiation Preservation Division, Quartermaster Food and Container Institute for the Armed Forces, 1819 W. Pershing Rd., Chicago 9, Illinois.

are a notable feature of our society. In graduate school one at least glimpses freedom within himself. Only as a scholar, finally, does he approach true freedom—if he is not distracted.

Elements of an Education in Food Technology

The education of a Food Technologist should encompass not only disciplining the student in the knowledge of the science, but should include development of the humanistic core of the individual as well. The product should not be solely an ornament for society but a vital contributing part of it.

The program for educating and training a Food Technologist may be designed on the basis of its elements in the broad sense. A listing of the elements would include:

I. The Learning Process and Communications. The learning process involves motivation, inductive and deductive reasoning, analysis and synthesis of information, and such other items as neatness, accuracy, ability to meet pressures, alertness and good health, and the organization of work. The learning process is a life-long experience, and is the process of self-education.

The ability to communicate both orally and in the written languages (of native and foreign tongues) is of the utmost importance. Pictorial (drawing) and symbolic (mathematics) communications are also essential.

II. Natural Phenomena and Concept. A broad foundation in the physical and biological sciences is essential in the education of Food Technologists. The cumulative knowledge of natural phenomena and concepts gives depth and understanding to the student. Training in mensuration, units and symbols, and computation gives the student flexibility. Laboratory experience gives the student confidence, proves text material, focuses classroom activity more clearly, develops skills, familiarizes him with the tools of science (the language, instruments, processes) and develops management and organization experience.

The methods of analysis and synthesis are instilled in the student. He learns to identify problems, establish ideal systems, set boundaries to the scheme, apply fundamental knowledge to systems, and predict behavior. The student finds that there may be many approaches to the solution of a problem.

III. Man's Foods. The student should become versed in the knowledge of the foods of man. This subject matter should include the history of foods and agriculture, and the production, composition, analysis, preservation, processing, marketing and utilization of foods for the buoyant health for man.

The modern food industry covers a multitude of processes for the manufacture of many hundreds of products. Commercial food processing of the present and past should be reviewed, following each step from the procurement of raw materials to the packaging of the finished commodity and the disposal of waste. In the limited time available, the student should be exposed to the major processes by means of laboratories.

Students should visit food plants of many types and forms; summer employment in the food industry should be an integral part of the program.

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IV. Integration of Knowledge. As the student progresses he should be encouraged to seek ways and means of correlating and integrating the fundamental knowledge he has accumulated of Food Technology. The student should be familiar with the tools and techniques and methods of adjacent professional groups.

It is equally important that the student understand the ideas of men and develop an appreciation of values. The student should be given the information to develop his educational, social, spiritual, human, professional, economic, and personal values, and a code of ethics. The student should be encouraged to develop his own intellectual structure, with individuality.

V. Creativity. It is not sufficient for the student, old or young, to sit and marvel at the cresting of civilization, partaking of its benefits but contributing little to the flow. The student has the opportunity to create in himself the unique individual and to contribute to society that which, but for him, might not be done. In the final analysis, each man has his own goals, differing at least in degree and direction. Certainly this contributes to making life interesting, meaningful, and challenging.

For convenience, one may classify mental powers in four levels. Man has absorptive power or the ability to apply attention and to observe. He has retentive power or the ability to memorize and recall. The student has reasoning power, or the ability to analyze and to judge. He also has creative powers, or the ability to visualize and to generate ideas. It is easier to judge than to create. Electronic computers are capable of performing feats of judgment, but can not achieve creative imagination. Creative imagination can be defined as the will working on the data of memory, acting as a searchlight, beaming from the known to the unknown, and, to discovery and invention!

Creative thinking is a conscious effort to discover. One may operate creatively by extending the horizon of information in that segment of knowledge in which one is disciplined. Such are generally the areas of the scientist and the inventor. The measure of man is in the quality and quantity of contributions at the horizon of the branch of knowledge in which he is disciplined.

All men have creative powers, differing in degree, and in their use. Invention may be defined as originality with a quality of value. It is a simple matter to be original if value is omitted. No one has yet discovered the method for cultivating creative genius. Some men have extraordinary capacity, however, to stimulate others to achievement.

Many conventional technologists are skeptical of the very existence of the unknown, and lack the emotional drive to achieve capital invention. Unless properly stimulated, they stay with their facts and never take exploratory voyages. It is necessary that students be developed who can conceive of unknown places to explore, have the daring to start, and the determination and patience to succeed. The future belongs to that society which not only recognizes but cultivates creative genius.

Some wise old man gave a group of tired business men the following bit of philosophy:

"If you keep your nose to the grindstone rough
And keep it down there long enough
You'll soon forget there are such things
As brooks that babble and birds that sing.
Three things your world will soon compose
Yourself, the stone, and your ground down nose."

As men, we need some clear, creative thoughts if we are to solve that ageless problem of adequate food for all men. It is wishful thinking to believe the problem will solve itself if we ignore it.

The solution of the problem of food for man will be obtained only from alerted minds. Man can not solve problems he does not know exist. Answers are harvested from inquiry into natural phenomena. Results are obtained by the application of the new information for the betterment of mankind. The story of man's food is an integral part of the story of man.

The future of mankind rests heavily upon educated Food Technologists. Can we meet the challenge?

Acknowledgments

I should like to recognize the assistance given by my associates at this University in the development of these concepts of the elements of an education in science.

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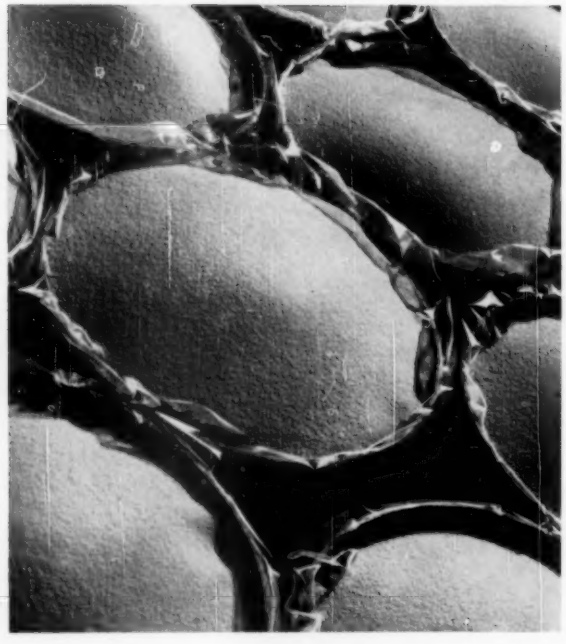

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IFT News

PUGET SOUND

The Fall meeting of the Section, held in Seattle, featured a talk by Dr. Paul Trussel of the British Columbia Research Council on "Bacterial Spoilage In Shell Eggs and It's Control." Approximately 40 members, wives and guests attended.

An informal breakfast get-together with the Oregon Section of Food Technologists was convened January 8 in conjunction with the annual meeting of the Northwest Canners and Freezers Association in Seattle January 6, 7, 8.

—Maxwell E. Gibson, Jr.

W. NEW YORK

Mr. Charles K. Brett, Supervisor Marketing Investigations, Commercial Research Department, Continental Can Company, Inc., New York City, addressed the December 17 dinner meeting at the Hotel Markeen, Buffalo, N. Y. This meeting being a "Ladies' Night" event, Mr. Brett's topic "How Consumer Preferences Help Us" was appropriate for the occasion.

DIXIE

The Section held its Fall meeting at the Briarcliff Hotel in Atlanta, Georgia. Dr. Martin S. Peterson, editor of FOOD TECHNOLOGY and *Food Research*, was the guest speaker. Dr. Peterson reviewed briefly the growth and scope of food research literature with special reference to the IFT journals. He also called attention to the improvement in technical writing over the years but stressed the continued need for good organization, for clear-cut, evidence-based interpretation of the data, and for economy in wordage, tabulation, and illustrative matter. The latter is sometimes a luxury rather than a necessity. Mathematical equations used in statistical exposition are perhaps the most expensive items in printing and should be carefully checked for accuracy to avoid resetting.

The acute need for organizing food research and engineering literature for ready retrieval was discussed. This need is universal in the scientific and technical world but it would help greatly if each of the technical fields could establish a facility to control its growing bibliography. As a sidelight, the speaker remarked upon the impact of developments looking toward space travel. Research on food for space voyages may become a respected project and develop a substantial literature sooner than we might expect.

—Cora Ellis

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NEW YORK

"A new era of foods tailored for the nutritional needs of various segments of our population" was described by Carl B. Henrichson of the Du Pont Company at a recent meeting of the New York section. He compared the "tailormade food era" with the development of "convenience foods" and the elimination of seasonal variations and quality variations in foods available to American tables.

"Each of these achievements," he said, "was the result of the inventiveness and imagination of food technologists, and the ability of the food industry itself to envision and satisfy the needs of the American consumer. . . . Now there is a need for low-calorie foods that will satisfy the appetite of the American consumer who tends toward overweight, and enable him to continue to enjoy eating and yet avoid the health problem that comes from over-consumption of calories."

Carl B. Henrichson

Mr. Henrichson went on to point out that nonnutritive sweeteners, such as calcium and sodium cyclamates and saccharin, represent only one avenue for reducing calorie consumption or for weight control.

"However, since artificially sweetened foods increase the variety and the amount of foods that can be consumed within a dietary caloric allotment, they make calorie controlled diets more enjoyable," he declared. "These nonnutritive sweeteners are only part of the answer in reducing the calories in a given food item. They take care of the sweet flavor, but they do not affect the calorie count of fats and starches in the recipe—and they do not provide the physical qualities of the sugar which they replace."

Pointing out that it may be possible to satisfy various appetities for normal calorie foods with low-calorie items which are unlike conventional foods, Mr. Henrichson stated: "It has been our conclusion that one of the biggest obstacles standing in the food technologist's way in the development of dietetic low-calorie foods is their desire to duplicate conventional foods."

Using jelly as an example, he cited the difficulty of producing a good quality jelly without sugar. "However, is duplication necessary?" he asked. "Would we not be able to reach this market and satisfy the jelly appetite with a new fruit spread that serves the same end use? . . . We can carry this same kind of thinking into other low-calorie foods and food fields —not duplicating or imitating but developing a product which will appeal to a given appetite. . . .

"The key to success in the development of low-calorie food products," he concluded, "lies not in trying to duplicate normal calorie foods, but in the ability of food technologists to create new, low-calorie food concepts which will satisfy our various appetites."

TEXAS

The winter meeting of the Section was held in Houston on December 12 at the Ben Milam Hotel. The formal meeting was preceded by a social dinner hour. Following the business session, Dr. Raymond Reiser of the Biochemistry and Nutrition Department, Texas A. & M. College, spoke on "The Fat We Eat." The possible relation of human disease to fat in the diet precipitated a stimulating discussion period following his talk.

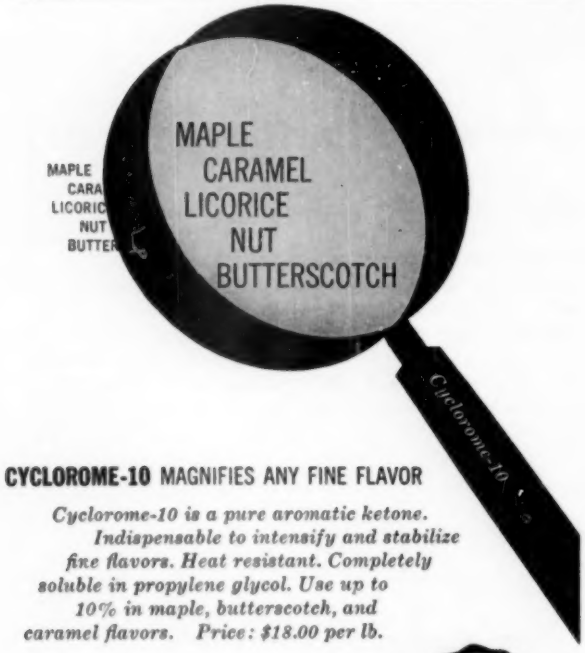
—E. E. Burns

PHILADELPHIA

The feature of the December meeting was a discussion of coffee, the topic being "All About Coffee." Speaker was Dr. Frederick R. Greenbaum, Research Chemist of Kwik Kafe Coffee Processors, Hatboro, Penna. Dr. Greenbaum has a background of some 30 years experience as a teacher, lecturer, and researcher in the pharmaceutical, medical and chemical industry. With the aid of a color film, he explained the history, cultivation and processing of the coffee bean, together with information on the chemical and physiological aspects of coffee. The question and answer period following the discussion inevitably led to the subject "How does one make a good cup of coffee?"

The December meeting was our annual "Christmas-Ladies' Night." It was a great success. The Section is looking forward to the February meeting, the topic of which will be "The Freeze Drying of Foods."

—Fred B. Jacobson



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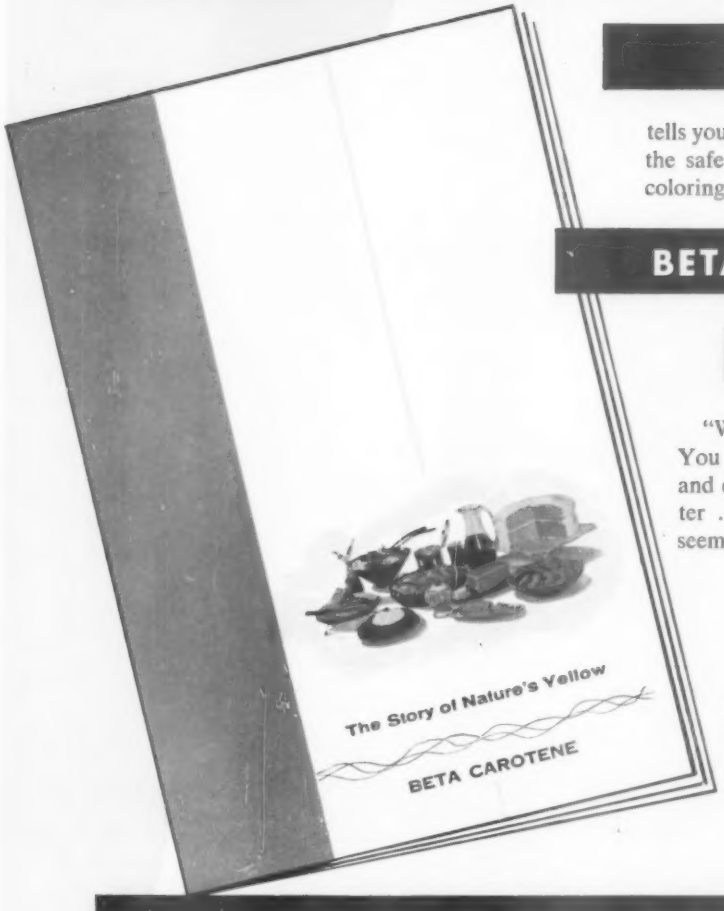

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Literature

BOOKS

THE FREEZING PRESERVATION OF FOODS—VOLUME II —Freezing of Precooked and Prepared Foods. Donald K. Tressler and Clifford F. Evers. The Avi Publishing Company, Inc., Westport, Connecticut. 1957.

In recent years, the trend to produce convenience foods for retail consumption and portion control foods for institutions has been growing at a phenomenal rate. Year by year, more items are available to reduce the homemakers' "kitchen time" and eliminate food and labor waste in public feeding establishments. The concept of prepared, precooked and pre-portioned foods has become accepted so rapidly, that this new important segment of the frozen food industry is eventually expected to become the top sales item in the retail freezer cabinet. For institutions, as labor costs rise, the tendency to produce prepared frozen foods for feeding establishments in central commissaries and/or purchase prepared portioned frozen foods from manufacturers will spread as more organizations awaken to the savings made and control of quality possible in this system of food preparation.

The foregoing observations are well documented in the newly published Volume II of the *Freezing Preservation of Foods*. It is natural that Dr. Donald K. Tressler and Mr. Clifford F. Evers, should recognize this situation. Both authors have had a tremendous amount of experience in all phases of preservation of foods by freezing. For over twenty-five years, both have been convinced that the sale of prepared frozen products would become an accepted fact in marketing practice. They were members of a team at Birdseye Laboratories in the early thirties working on such items; their belief in the practicability of prepared foods is now justified. Their sense of timing in bringing the new volume to press now is proof of their understanding of the prepared frozen food field.

Everything ever published has been considered

This new volume of the augmented edition is a compilation of a mountainous amount of data about the full line of prepared frozen foods. Most of the data presented is not original with the authors. It represents an extremely fine review of the literature available; compiled, reviewed, summarized into concise statements and integrated with other material into a book assembled on a definite plan; namely, classification by product. All of the literature known to the reviewer in the course of reading on this subject for 10 or 12 years appears to be included. The more the volume is studied, the stronger is the belief that everything ever published on the subject has been considered by the authors for inclusion.

Before this book appeared on the scene, it was necessary to study a variety of trade publications, professional society journals and abstracts, in conjunction with books and articles written for the home freezer to obtain data for use in the commercial prepa-

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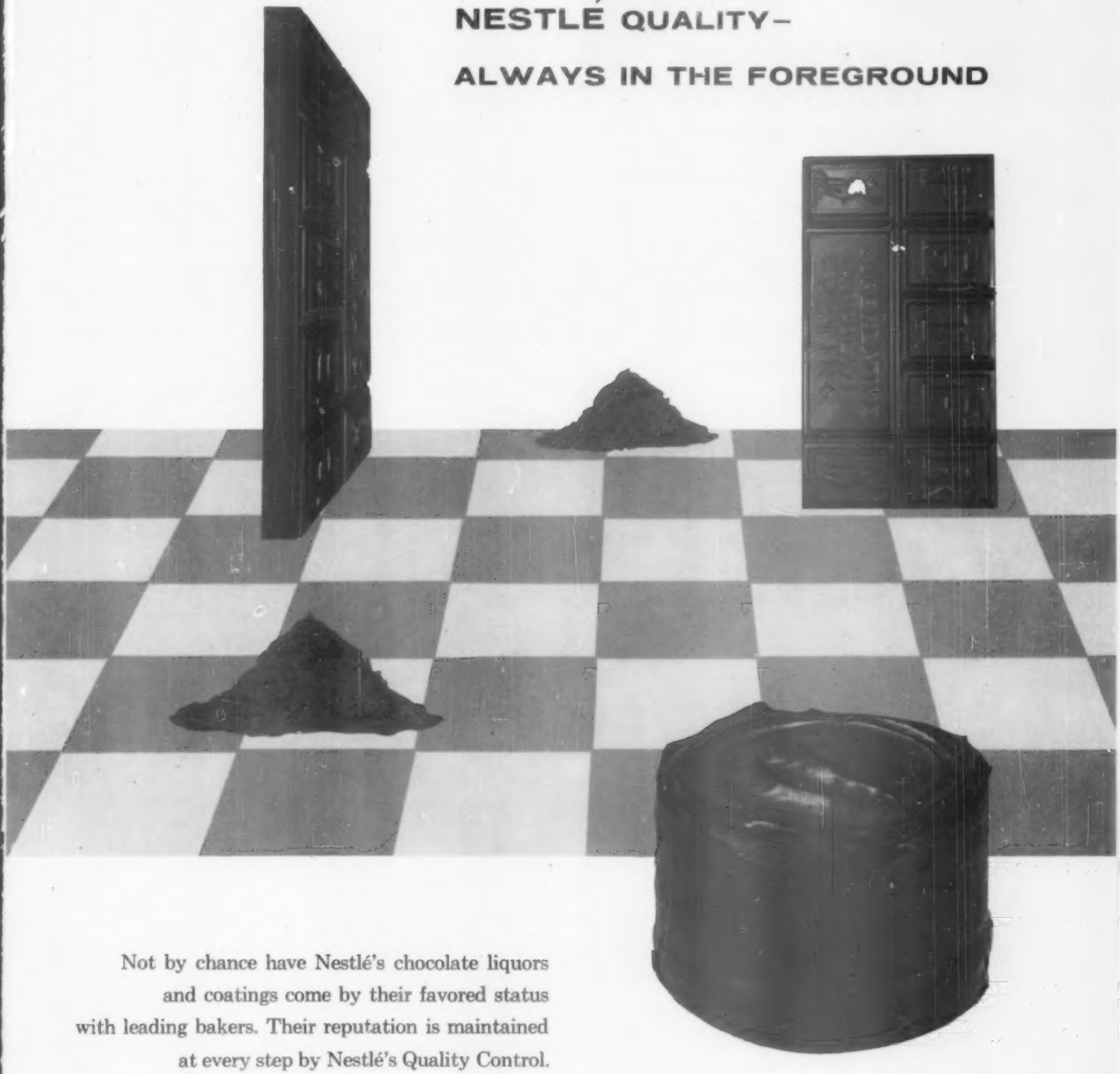

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ration of precooked frozen foods. Here for the first time is a reference book prepared for and shaped to industry use. Perhaps more useful to the small packer than to the large firm with its own research staff, it is nevertheless a reference for everyone connected with research or production of prepared foods. It is particularly valuable because of the well prepared and annotated bibliography at the end of each chapter.

Although much is now known about the freezing of cooked foods, none can predict with certainty the storage life of a new product. The data presented in chapter 22, listing those products with anticipated short, medium, and long storage limits are invaluable.

The authors succinctly summarize the problems of the frozen food producer in one sentence (Chapter 22, Storage of Precooked Frozen Foods): "However, the authors have evidence to indicate that if sufficient care is taken in the selection of the formulas used, the ingredients chosen, the method of cooking employed, and the packaging materials and method of packaging used, products . . . can be produced which will retain their fresh qualities. . . ." The period of time mentioned is not important. But it is important that the authors know how to produce quality products of long stability and realize the effect of improper ingredients, methods of cooking, and packaging. In this respect they differ from other authorities, and they so state in this chapter.

A major weakness in the book, in the reviewers opinion, is best expressed by a quotation following the one shown above: "It is dangerous to draw too sweeping generalizations concerning the probable storage life of any *CLASS* of products." Each and every detail must be considered individually—appears to be the philosophy of the authors. In view of the avoidance of general considerations, the reader is presented with the problem of struggling to sift for the conclusive opinion a tremendous mass of data. Perhaps this feeling is peculiar only to the person who reads the entire volume page by page. Perhaps the reader using the book for reference will not feel the burden of too many quotations from the authorities. However, the problem will face students required to read the entire volume and those who attempt to orient themselves in the same fashion.

The other weakness apparent to the reviewer is the use of old formulas and data without revision from the earlier chapter in the previous editions. Page after page of recipes or formulas are presented. Some of them follow all of the advice given by the authors in other chapters. Others, not revised, could cause grief to producers attempting to use them without change. Some of the data presented on the palatability of precooked foods reheated by varying methods and equipment is now outmoded and not in agreement with recent data obtained in private surveys made by industry. It is true that these data have not been published, but research circles must be cognizant of these facts. New packaging methods discussed in this volume account for some of the reviewer's difference of opinion with the data.

In general, however, the authors present a balanced understanding of both research and practical production problems. The book is exceptional in its survey

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of the new industry—literally, from soup to nuts. Special information is presented about feeding establishment use and preparation of frozen foods in data supplied the authors by the National Restaurant Association. Frequent reference is made to work performed for and by Government agencies as well as extracts from the current military specification for Meals, Pre-cooked, Frozen. There is a good description of the present use of such meals by the U. S. Air Force, including menus and methods of reheating aboard aircraft.

Some outstanding chapters

The reviewer believes the following chapters to be the most distinctive because they present new and original information not available in complete form elsewhere.

Chapter 2—Special Problems in Preparing, Freezing, Storing, Transporting and Marketing

Chapter 3—Packaging

Chapter 12—Sauces and Gravies

Chapter 21—Complete Meals

Chapter 23—Handling and Use of Frozen Pre-cooked Foods—Special Reseating Equipment

Chapter 24—Food Freezing and Use of Frozen Foods in Public Feeding Establishments

For those interested, there are chapters covering in generous detail each type of frozen foods as classified by the authors. Chapters covering Poultry Products and Pot Pies; Pre-cooked Vegetables; Nationally Foods; Fruit Products; Ice Creams and Sherbets; three chapters on Baked Products; and also one on a product new to freezing, Confections.

Summing it up, *The Freezing Preservation of Foods*, Volume II is an excellent text for schools; for industry, an excellent reference; for public feeding establishments, a guide to future development; for the public in general, a manual of information not previously known outside of research circles.

JOSEPH W. BARCLAY
Seabrook, New Jersey

ATOMIC ENERGY IN AGRICULTURE. William E. Dick. Philosophical Library. New York, N. Y. 150 pages.

Progress on the peaceful uses of the atom as it affects the agricultural sciences is delineated in this succinct and interesting book. The author has made use of several of the outstanding papers presented at the international conference (1955) at Geneva. Scope of the work begins with "remaking crop plants with radiation" and ends with "atomic radiation and food preservation." The author of *Atomic Energy in Agriculture*, who has worked as a research biologist and also as an editor of chemical journals, addresses the general science reader.

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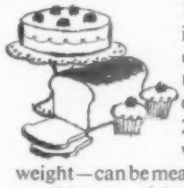

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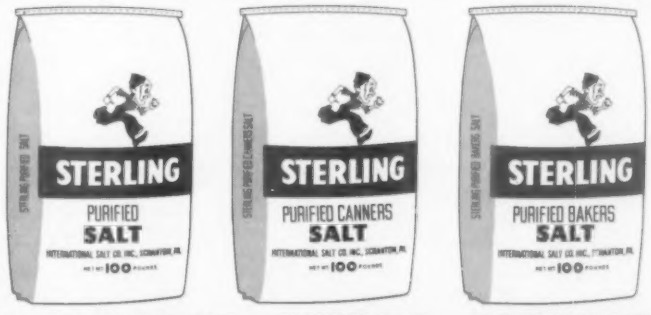

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CLOUDS OVER DESTINY. Charles Raymond Stumbo. Vantage Press, New York. $3.75.

At the opposite pole from food science and technology, *Clouds Over Destiny* deserves, nevertheless, a review in a food journal. For one thing, it is an event of considerable interest for the simple reason that it was written by a scientist. To be literate in science as well as letters is an achievement not to be disregarded. A certain amount of antagonism between the arts and sciences, exhibited, if nowhere else, in academic circles, has given rise to the notion that an artist cannot be literate in the sciences and a scientist cannot be literate in the arts. Both viewpoints are *non sequiturs*.

C. R. Stumbo

Clouds Over Destiny portrays the simple, relatively uncomplicated culture of a Kansas farm family and the rural community of which they are a part. The country doctor, the newly-arrived, attractive school-marm, the blunt-spoken Scandinavian farmer—all are there. Into this intensely integrated community the author introduces a fugitive from a Californian urban environment, a professional man who has had to escape from an impending "John Doe" criminal charge; namely this, leaving the scene of an auto accident. Add to these elements of the story, the fact that the victim of the hit-and-run accident is a young girl, and you have the materials for this study of how a stranger, disturbed in mind, is rehabilitated by the emotional steadiness, realistic attitudes, and ideals of conduct of this Kansas rural community. To appreciate the values of *Clouds Over Destiny* requires a sophistication that rises above any weighting of urban over rural attitudes or setting one's own environment or beliefs or sentiments above those set forth in Stumbo's novel. This is an earthy "great outdoors" world that we enter as we get out of the boxcar with the hero, Rod Banyon, as he chooses to call himself, and find ourselves in the sunny dry air of the Kansas plain. The story from that point on is the story of a man who, because of paternal domination during childhood and youth, has never "belonged" but who, now, for the first time in his life, can share in the toil, social activities, habits, beliefs, troubles, and triumphs of a cultural entity, rural Kansas, and—eventually—be accepted. The path is not always easy. The hero, though adult in years, must submit to the rites of "coming-of-age" in Kansas—conquering, with his bare firsts, a rural bully, accepting with equanimity some practical jokes of the good old farm type, and perpetrating some of his own in return. On pain of not being accepted, he even has to change over from classical to colloquial grammar on occasion. But with eagerness, he participates to the full in the culture which, day by day, is regenerating his badly stunned mind and heart. If we can think of American life as controlled by regional interpretations of our basic ideas, institutions, and behavior patterns, here, in *Clouds Over Destiny*, is an interesting projection of those controls as expressed in rural Kansas, circum 1928. If the sun shines a little brighter in Kansas, so also do many of our national sentiments.

The concluding chapters of *Clouds Over Destiny* concern the culmination of the romantic episode of the novel. Stumbo's narrative talent is at its best in these chapters and they add substantially to the structure of the book. In these chapters the events in the lives of the hero and heroine, only shadowed in the earlier pages, come into clear view. The purge of doubts and frustrations that have beset both leading characters also occurs, and one leaves the novel with the feeling that the strands of the story have been skillfully woven into a completed pattern.

Clouds Over Destiny is a contribution toward defining those determinants in the regional life of America that we can never know too much about. If this reviewer were writing a dictionary of motifs and social patterns in American literature, he would enter *Clouds Over Destiny* under *Regional Life, Kansas: language, customs, standards, psychology, environmental factors*. Under this last category, so help me, there would have to be a footnote on that comical piece of environmental equipment made famous by Chic Sale.

MARTIN S. PETERSON
Chicago, Illinois

LITERATURE ON FOOD RESEARCH AND TECHNOLOGY[1]

Commodities

Bulk milk handling; papers presented at the National Conference on Bulk Milk Handling, May 13–14, 1957. Compiled by Carl W. Hale and Donald L. Murray. East Lansing, Mich., Michigan State University and Agricultural Experiment Station, Departments of Engineering and Dairy, 1957. 112, 20 p. processed.

Papers presented at the first national conference cover various angles of handling and use of bulk milk tanks, and includes a report of two surveys of trends in use.

Dairy statistics. B. H. Bennet and others. Washington, U. S. Govt. Print. Off., 1957. 389 p. (U. S. Department of Agriculture. Statistical bulletin, no. 218.) pap. $1.75.

Demand for alternative forms of chicken meat. E. B. Hogan. Kingston, R. I., 1956. (Rhode Island. Agricultural Experiment Station. Bulletin, 334.)

Fluid and dry milk consumption in Rhode Island, by M. I. Zawadzkhi and I. W. Mitchell. Kingston, R. I., 1957. 21 p. (Rhode Island. Agricultural Experiment Station. Bulletin 338.)

A study of the changes in consumption from 1950 through 1954, correlated with economic and temperature factors.

Semaire d'etude sur 66 problème des oligéléments dans la vie végétale et animale, 24-IV-1955. Citta del Vaticano, Ed. Pontificia Academia Scientarum, 1957. 617 p. (Pontificate Academiae Scientarum scripta varia, 14.)

A series of articles on various phases of the problem of trace elements and microelements in both plants and animals. Articles in various languages including Italian, English, German and Spanish.

[1]Material for this list should be sent to Dr. James G. Hodgson, Chief, Library Branch, Quartermaster Food and Container Institute for the Armed Forces, 1819 W. Pershing Road, Chicago 9, Illinois.

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Food Engineering

Drying farm crops, by Carl W. Hall. Ann Arbor, Mich., Edwards Brothers, 1957. 336 p.

Published by the Agricultural Consuling Associates, Inc. of Reynoldsburg, Ohio the book covers both practical and technical phases of the drying of farm crops.

Home freezing and canning by households in United States by region. Washington, U. S. Govt. Print. Off., 1957. 72 p. (U. S. Department of Agriculture. Household food consumption survey, 1955, Report 11.) pap. $0.45.

Chemical Aspects

Bakteriologische Grundlagen der chemotherapeutischen Laboratoriumsprazis. Berlin, Springer, 1957. 210 p. Lw 39.60.

Biochemistry of some peptide and steroid antibodies. E. P. Abraham. New York, Wiley, 1957. 107 p. (CIBA lectures in microbial biochemistry.)

Recent progress in the bacitracins and two families of cephalosporins. Author is Senior Research Officer at Sir William Dunn School of Pathology, Oxford University.

Chemical methods for analysis of fruit and vegetable products. Ed. by J. A. Ruck. Summerland, B. C., 1956. 70 p. processed. (Canada. Department of Agriculture. Science Service. Contribution no. 350.)

Dynamic aspects of biochemistry, 3d ed. Ernest Jay Baldwin. New York, Cambridge University Press, 1957. 545 p. $5.50.

A considerable number of revisions over previous editions, with some new material.

Mineral nutrition and the balance of life. Frank Albert Gilbert. Norman, Okla., University of Oklahoma Press, 1957. 365 p. $5.95.

Minerals and their significance to health in both plants and animals. A 72 page bibliography.

Physical Sciences

Advances in radiobiology; Proceedings of the Fifth International Conference on Radiobiology held in Stockholm on 15th–19th August 1956. Edinburgh, Oliver and Boyd, 1957. 77 s 6 d.

Includes material on irradiation.

Atomic energy and agriculture; a symposium presented on December 27–29, 1955, at the Atlanta meeting of the A.A.A.S. C. L. Comar and others, eds. Washington, American Association for the Advancement of Science, 1957. 460 p. (AAAS Publication no. 49.) $9.50.

Includes material on food preservation by irradiation.

Nuclear radiation in food and agriculture. W. Ralph Singleton. Princeton, N. J., D. Van Nostrand Company, 1957. 380 p. (The Geneva series on the Peaceful Uses of Atomic Energy. Dr. J. G. Becherley, General Editor.) $7.50.

Part VII. Food sterilization. Cold sterilization of foods. Radiation control of trichinosis.

Economic Aspects

Analysis of short time changes in price of butter at Chicago. Robert W. March, Elsie D. Anderson, and Jack E. Klein. Washington, U. S. Govt. Print. Off., 1957. 67 p. (U. S. Department of Agriculture. Marketing research report, 194.) pap. $0.40.

Demand and price structure for dairy products. Anthony S. Rajho. Washington, U. S. Govt. Print. Off., 1957. 252 p. (United States. Department of Agriculture. Technical bulletin, 1168.) pap. $0.30.

The measurement of levels of living with special reference to Jamaica. London, H. M. Sta. Off., 1957. (Colonial research studies no. 24.)

ABSTRACTS

ANALYTICAL METHODS

Detection of chromatographic spots in paper.

SZENT-GYORGYI, A. (Marine Biol. Lab., Woods Hole, Mass.). *Science 126*, 751 (1957).

Chromatographic spots not detected at room temp. were visible upon cooling by liquid nitrogen or dry ice. This method does not entail the alteration of substance to be tested.

Standards for pH measurements from 60° to 95° C.

BOWER, V. E. AND BATES, R. G. *J. Research Natl. Bur. Standards 59*, 261–4 (1957).

The NBS standard pH scale is defined in terms of several reference solns. whose pH values (pH_s) have heretofore been assigned only in the range 0° to 60° C. Recent measurements of the standard potential of the silver-silver-chloride electrode at temps. above 60° now permit this scale to be extended to 95° C.

Titration of mixtures of acids.

SIMS, D. AND PETERS, L. (Dept. of Textile Ind., Univ. of Leeds). *Nature 180*, 805–6 (1957).

Formulae are given for the calculation of titration curves of a mixt. of a strong and a weak acid. The detn. of the degree of polymerization of polypeptides by end group titration also involves a detn. of the amt. of weakly acidic carboxyl group in presence of a large excess of the base of a stronger acid.

Ion exchange micromethods for separation of fermentation acids. Determination of fumaric acid in fermention broth.

VANETTEN, C. H. AND MCGREW, C. E. (Northern Regional Research Lab., U.S.D.A. Peoria, Ill.). *Anal. Chem. 29*, 1506–9 (1957).

Use of ion exchange resins to sep. fermentation acids prior to titration provides a simple and rapid method for acid detn. with a micro ion exchange column and samples of the order of 0.15 meq. of total acids led to the development of a rapid method for detn. of fumaric acid in fermentation broths. Recovery of added fumaric acid was 98.2%, with standard deviation of 1.52. Method also gave information concerning total acidity of fermentation broth and the nature of the remaining acids present.

Glass electrode for measuring sodium ion.

EISENMAN, G., RUDIN, D. O. AND CASBY, J. U. (Eastern Penna. Psychiatric Inst., Phila.). *Science 126*, 831–4 (1957).

The authors conclude that a sodium aluminosilicate glass containing 11 moles per cent of Na_2O, 18 moles per cent of Al_2O_3, and 71 moles per cent of SiO_2 offers electrodes of practical usefulness for selectively measuring the sodium ion activity as a continuous function of time in certain ionic mixts., including extracellular biol. fluids.

BIOLOGICAL SCIENCES

Biochemistry

A study of the metabolism of theobromine, theophylline, and catteine in man.

CORNISH, H. H. AND CHRISTMAN, A. A. (Dept. of Biol. Chem. Med. School, Univ. of Michigan, Ann Arbor). *J. Biol. Chem. 228*, 315–23 (1957).

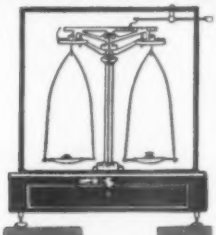
After suitable control periods on diets low in methylated purines, two human subjects received 1 g. doses of theobromine, theophylline, and caffeine. Sixty-two per cent of the theobromine, 77% of the theophylline, and 66% of the caffeine were excreted in the form of methylxanthines and methyluric acids during the subsequent 48 hrs. The major part of the theobromine was excreted as methylxanthines. In contrast, the methyluric acids were the predominant excretory products of theophylline. After caffeine administration, approx. equal amts. of the methylxanthines and methyluric acids were present in the urine.

Ascorbic acid catabolism in guinea pigs.

SALOMON, L. L. (Dept. of Biochem. and Nutrition, The Univ. of Texas, Galveston). *J. Biol. Chem. 228*, 163–70 (1957).

The effect of toxin stress and scurvy on the rate of catabolism of ascorbic acid has been investigated and found to follow first-order kinetics in normal, scor-

A LITTLE



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Factors Affecting the Quality of Prepackaged Meat

II. E. Determining the Proportions of Heme Derivatives in Fresh Meat [a,b,c]

Hormoz Broumand, C. Olin Ball, and Elizabeth F. Stier

Departments of Food Technology and Animal Husbandry, Rutgers University, New Brunswick, New Jersey

(Manuscript received March 20, 1956)

SINCE THE COLOR of meat depends upon the chemical state of the meat in respect to myoglobin derivatives, a method of determining the relative concentrations of these derivatives in meat constitutes an important adjunct to the techniques of any study of this subject. A spectrophotometric method used rather extensively for making this determination is described by Lemberg and Legge *(1)*.

PRINCIPLES

When a parallel beam of monochromatic light passes through a homogeneous medium, the intensity of the beam diminishes exponentially with the thickness of the medium. If I_o is the intensity of the incident beam, I, that of the emergent beam, l, the thickness of the medium in centimeters, and d, the optical density or absorbancy, as read on the spectrophotometer, we have the relationship,

$$E = \frac{\log(I_o/I)}{l} = \frac{d}{l} \qquad (1E)$$

where E is the extinction coefficient. It is noted that, since d varies with concentration of the solute, E also varies with concentration. By definition,

$$E_{mM} = \frac{E}{C_{mM}} = \frac{d}{C_{mM}l} \qquad (2E)$$

where E_{mM} is the millimolar extinction coefficient and C_{mM} is the concentration of the solute in millimoles per liter.

Since, in a solution in which the dissolved molecules are independent of one another and are equally influenced by the molecules of a colorless solvent, the absorbancy d of a given thickness of solution at any wave length is accepted to be a linear function of the concentration C_{mM} of the solute, we have, for a given wave length

$$d = SC_{mM} \qquad (zE)$$

where S is the slope of a straight line showing the relationship between d and C_{mM} when wave length and the dimensional thickness of the solution are constant.

From (2E) and (zE)

$$E_{mM} = \frac{S}{l} \text{ and } l\,E_{mM} = S$$

Thus, at a given wave length, E_{mM} is independent of the concentration of the solute. When C_{mM} is constant, however, (2E) shows that E_{mM} varies directly as d and varies inversely as l. When both C_{mM} and l are constant, the maximum E_{mM} value occurs at the same wave length as the maximum d value.

It is clear from eq. (2E) that, for a given solution in a given thickness (C_{mM} and l are constant), the ratio of the millimolar extinction coefficients at 2 different wave lengths is equal to the ratio of the measured absorbancies, d, of the solution at the same 2 wave lengths.

Curves published by Bowen *(2)* plotting millimolar extinction coefficients of solutions of pure oxymyoglobin, metmyoglobin, and reduced myoglobin against wave lengths of light (Figure 1) show that the extinction coefficient of any solution containing only myoglobin, oxymyoglobin, and metmyoglobin in the pure state lies within the limits shown for various wave lengths in Table 1; also that at each of the 5 wave lengths 507, 527, 553, 573, and 593 mμ, the extinction coefficient of myoglobin is the same as that of oxymyoglobin; at each of the 3 wave lengths 473, 525 and 597 mμ the extinction coefficient of oxymyoglobin is the same as that of metmyoglobin; and at each of the 3 wave lengths 462, 523 and 606 mμ, myoglobin and metmyoglobin have identical extinction coefficients. These are wave lengths at which isobestic points (intersections) occur in the system of 3 curves.

TABLE 1

Ranges of millimolar extinction coefficients of three myoglobin derivatives at various wave lengths

in mμ	Range of E_{mM} of the solution
462	7.7– 9.5
473	4.4– 7.6
507	5.6– 9.9
523	6.7– 7.7
525	7.5– 7.8
527	7.3– 7.9
553	4.3–12.7
573	3.0–10.6
593	3.0– 5.8
597	3.0– 5.1
606	1.6– 3.1

PROCEDURE

After this discussion of principles, we may enter a description of the procedure for determining the concentrations of the myoglobin compounds. First step in the procedure described by Lemberg and Legge *(4)* is to measure the absorbancy values of the extract at three different wave lengths, λ′, λ″, λ‴. Inasmuch as the extinction coefficients of all dissolved compounds in an extract are additive at all wave lengths, from equation (2E), we may write,

For wave length λ′, $E' = E'_{mM(Mb)}\,C_{mM(Mb)} + E'_{mM(O_2Mb)}\,C_{mM(O_2Mb)} + E'_{mM(MMb)}\,C_{mM(MMb)}$ (1)

For wave length λ″, $E'' = E''_{mM(Mb)}\,C_{mM(Mb)} + E''_{mM(O_2Mb)}\,C_{mM(O_2Mb)} + E''_{mM(MMb)}\,C_{mM(MMb)}$ (2)

For wave length λ‴, $E''' = E'''_{mM(Mb)}\,C_{mM(Mb)} + E'''_{mM(O_2Mb)}\,C_{mM(O_2Mb)} + E'''_{mM(MMb)}\,C_{mM(MMb)}$ (3)

[a] A report of work conducted by contract with the Bureau of Animal Industry, U. S. Department of Agriculture, with funds provided under the Research and Marketing Act.

[b] Paper of the Journal Series, N. J. Agricultural Experiment Station, Rutgers University, The State University of N. J.

[c] The first published report on this work appeared in a thesis: "The Development of a Spectro-Photometric Method for Estimation of the Pigmented Compounds of Meat" by Hormoz Broumand, Rutgers University, July, 1953.

E', E'', and E''' are extinction coefficients of the solution, are linear functions of the absorbancy values, and therefore vary with the overall concentration of the substances in solution. These values are calculated by equation (1E) from the absorbancy values of the solution as read on the spectrophotometer.

$E'_{mM(MMb)}$, $E''_{mM(MMb)}$, and $E'''_{mM(MMb)}$ are the millimolar extinction coefficients of reduced myoglobin at wave lengths λ', λ'', and λ''', respectively.

$E'_{mM(O_2Mb)}$, $E''_{mM(O_2Mb)}$, and $E'''_{mM(O_2Mb)}$ are the millimolar extinction coefficients of oxymyoglobin at wave lengths λ', λ'', and λ''', respectively.

$E'_{mM(MMb)}$, $E''_{mM(MMb)}$, and $E'''_{mM(MMb)}$ are the millimolar extinction coefficients of metmyoglobin at wave lengths λ', λ'', and λ''', respectively.

Values of these millimolar extinction coefficients are taken from Figure 1. Thus, the values of all symbols in equations (1), (2), and (3) are known except $C_{mM(Mb)}$, $C_{mM(O_2Mb)}$, and $C_{mM(MMb)}$, the concentrations of the 3 compounds in millimoles per liter. These are obtained by solving the equations.

From the earlier discussion, it is seen that, if wave length λ' were 507, 527, 553, 573, or 593 mμ, $E'_{mM(Mb)}$ would equal $E'_{mM(O_2Mb)}$; if wave length λ'' were 473, 525, or 597 mμ, $E''_{mM(O_2Mb)}$ would equal $E''_{mM(MMb)}$ and if λ''' were 462, 523, or 606 mμ, $E'''_{mM(Mb)}$ would equal $E'''_{mM(MMb)}$. Confining the values of λ', λ'', and λ''' to these wave lengths, therefore, would somewhat simplify the solution of equations (1), (2) and (3).

Theoretical exploration of possible advantages lying in the use of these selected wave lengths for determining the relative concentrations of myoglobin derivatives in an extract brought to light the following considerations:

At any wave length, the value of the millimolar extinction coefficient, within the range shown in Table 1, depends upon the proportions existing among the amounts of the 3 compounds in the solution. A millimolar extinction coefficient measurement giving a value outside the range shown in Table 1 for the wave length at which the measurement is made is an indication that the solution contains some compound or compounds other than the 3 myoglobin modifications which are represented by the table. Extraneous compounds could be present even though E_{mM} were within the range specified, provided the amount of such compounds present is not sufficient to move E_{mM} outside the range.

In a solution of the 3 compounds, at any wave length at which 2 compounds have identical millimolar extinction coefficients, the proportions of these 2 compounds, in respect to each other, may be changed at will without affecting the extinction coefficient of the solution, as long as the proportion of the third compound to the combined amounts of the other two does not change. For example, at any of the wave lengths, 462, 523, or 606 mμ, the extinction coefficient for a solution containing oxymyoglobin and either reduced myoglobin or metmyoglobin or both, is constant as long as the per cent of oxymyoglobin in the total of the solute remains constant. If oxymyoglobin is 30% of the solute, the remaining 70% may be divided between reduced myoglobin and metmyoglobin in any chosen proportions without changing the value of the extinction coefficient.

A transposition of equation (3) demonstrates the truth of this statement mathematically. Assuming that

$E'''_{mM(Mb)} = E'''_{mM(MMb)} = E'''_{mM(Mb)(MMb)}$, we have

$$E''' = E'''_{mM(O_2Mb)}\ C_{mM(O_2Mb)} + E'''_{mM(Mb)(MMb)}\ (C_{mM(Mb)} + C_{mM(MMb)}) \qquad (3a)$$

Since $C_{mM(O_2Mb)} + C_{mM(Mb)} + C_{mM(MMb)} = 100$, it is clear that, as long as $C_{mM(O_2Mb)}$ remains constant, $C_{mM(Mb)}$ and $C_{mM(MMb)}$ may vary without restraint in relation to each other without changing the value of E'''.

These considerations motivated a study designed to discover whether or not the spectrophotometric determination of the relative concentrations of myglobin derivatives in meat could be either further simplified or improved in accuracy, or both, by the employment of a revised type of approach using only the wave lengths of isobestic points in the millimolar extinction coefficient curves. The study produced what we call the absorbancy ratio method, the development and testing of which will be described.

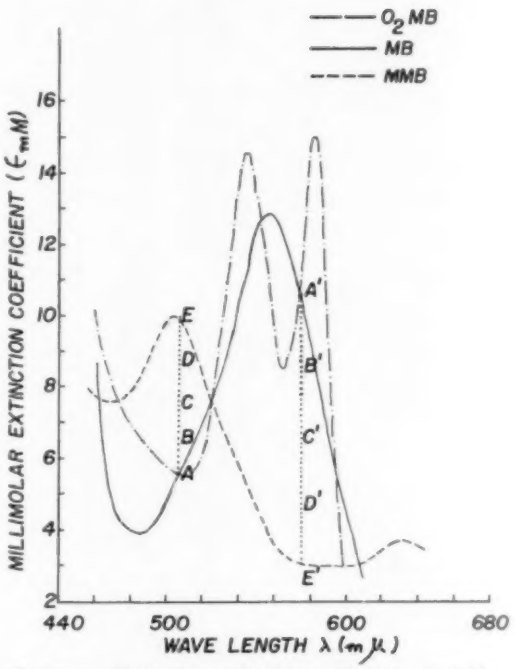

Figure 1. Millimolar extinction coefficients of O_2Mo, and MMb [Bowen (2)].

Observing Table 1, it is clear that at wave length 507 mμ, if $5.6 < E_{mM} < 9.9$, the solution may be assumed to contain X% metmyoglobin and $(100 - X)$% myoglobin and oxymyoglobin. A determination of $E_{mM} > 9.9$ or of $E_{mM} < 5.6$ at 507 mμ is taken as evidence that compounds other than myoglobin, oxymyoglobin, and metmyoglobin are present in appreciable quantities in the solution. On the basis of this reasoning, since the ratio of absorbancies for any 2 wave lengths equals the ratio of the extinction coefficients for the same 2 wave lengths, the value of $\frac{\text{(d) at 507 mμ}}{\text{(d) at 573 mμ}}$ of the solution containing 100% (Mb + O_2Mb) and 0% MMb $= \frac{(100 \times 5.6) + (0 \times 9.9)}{(100 \times 10.6) + (0 \times 3)} =$

$\frac{5.6}{10.6} = .528$ which is the ratio of $\frac{A}{A'}$ in Figure 1.

75% (Mb + O_2Mb) and 25% MMb $= \frac{(75 \times 5.6) + (25 \times 9.9)}{(75 \times 10.6) + (25 \times 3)} =$

$\frac{6.685}{8.70} = .767$ which is the ratio of $\frac{B}{B'}$ in Figure 1.

50% (Mb + O_2Mb) and 50% MMb $= \frac{(50 \times 5.6) + (50 \times 9.9)}{(50 \times 10.6) + (50 \times 3)} =$

$\frac{7.75}{6.8} = 1.140$ which is the ratio of $\frac{C}{C'}$ in Figure 1.

25% (Mb + O_2Mb) and 75% MMb $= \frac{(25 \times 5.6) + (75 \times 9.9)}{(25 \times 10.6) + (75 \times 3)} =$

$\frac{8.825}{4.9} = 1.801$ which is the ratio of $\frac{D}{D'}$ in Figure 1.

$$0\%\ (Mb + O_2Mb) \text{ and } 100\%\ MMb = \frac{(0 \times 5.6) + (100 \times 9.9)}{(0 \times 10.6) + (100 \times 3)} =$$

$\frac{9.9}{3} = 3.3$ which is the ratio of $\frac{E}{E'}$ in Figure 1.

Results of the above calculations for all percentages of metmyoglobin from 0% to 100% are shown in Figure 2 in which $\frac{\text{(d) at 507 m}\mu}{\text{(d) at 573 m}\mu}$ is plotted versus the relative concentrations of MMb and (O_2Mb + Mb). Calculations were made to obtain similar curves for ratios of absorbancies at other wave lengths mentioned. On the basis of the reasoning presented above, it was postulated that by calculating, for an extract of meat, the ratio of the absorbancy at 507 mμ to that at 573 mμ, one could learn the percentages of MMb and (O_2Mb + Mb) from the curve of Figure 2.

The following example will illustrate the method of calculation. If absorbancy (d) of an extract at 507 mμ = .221 and at 573 mμ = .118, $\frac{\text{(d) at 507 m}\mu}{\text{(d) at 573 m}\mu} = \frac{.221}{.118} = 1.873$. The value of 1.873 is located on the Y axis of Figure 2 (point a) and a line parallel to the X axis is drawn through this point until it crosses the curve at point b. From point b, a line parallel to the Y axis is drawn. The point of intersection with X axis (point c) indicates the percentages of metmyoglobin and of oxymyoglobin and metmyoglobin in the extract. It is shown that theoretically the extract contains 78% metmyoglobin and 22% oxymyoglobin plus myoglobin.

From the foregoing, it should be possible also to calculate the percentage of oxymyoglobin as compared to the combined percentage of metmyoglobin and reduced myoglobin or the percentage of reduced myoglobin as compared to the combined percentage of metmyoglobin and oxymyoglobin. The latter

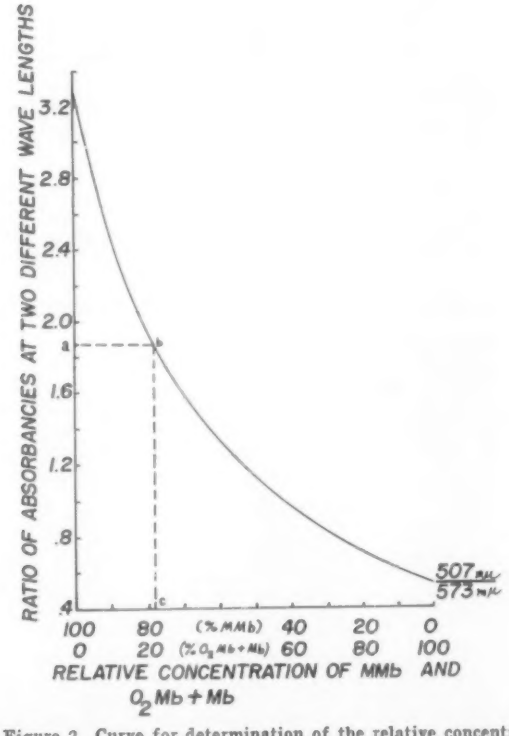

Figure 2. Curve for determination of the relative concentration of MMb and (O_2Mb + Mb) after measuring the absorbancies at 507 mμ and 573 mμ.

relationship was calculated using the wave lengths 473 mμ and 597 mμ, giving the curve of Figure 3 showing the relationship between the ratio of absorbancies and per cent of reduced myoglobin present.

Thus, in brief, the proposed procedure for estimating the relative proportions of myoglobin derivatives (expressed in

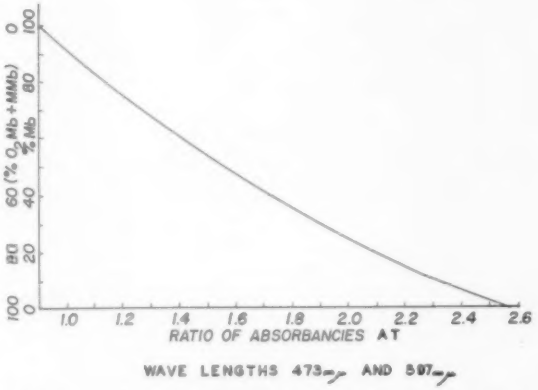

Figure 3. Curve for determination of the relative concentrations of Mb and (O_2Mb + MMb) after measuring the absorbances at 473 mμ and 597 mμ.

terms of molarity) in a meat extract consists of 3 major steps, as follows:

1. Using the absorbancy ratio $\frac{\text{(d) at 507 m}\mu}{\text{(d) at 573 m}\mu}$ estimate the percentage of MMb from the curve of Figure 2.
2. Using the absorbancy ratio $\frac{\text{(d) at 473 m}\mu}{\text{(d) at 597 m}\mu}$ estimate the percentage of Mb from the curve of Figure 3.
3. Estimate the percentage of O_2Mb from the equation $\%O_2Mb = 100 - \%MMb - \%Mb$.

The method holds promise of being helpful in facilitating the determination of the proportions of myoglobin derivatives in meat.

MODIFIED PROCEDURE WHEN ONLY TWO COLORED COMPOUNDS ARE PRESENT

In the special case in which only 2 colored compounds are present in the meat extract, theoretically it is possible to obtain the relative concentrations of the compounds from the values of the ratios of absorbancies of the extract at any two wave lengths.

If the solution contains only 2 colored compounds, it seems appropriate to base the ratio determination on wave lengths at which the extinction coefficients of the 2 compounds differ widely. For a solution containing only metmyoglobin and oxymyoglobin, a choice of wave lengths on this basis resulted in the use of 582, 544, and 564 mμ. The first and second wave lengths mark the positions of the 2 maximum values and the third, the position of a minimum value of the extinction coefficient of oxymyoglobin, according to Bowen *(2)* (see Figure 1). Using values based upon these 3 wave lengths, the curves of Figure 4 were calculated in a manner similar to that by which the curves of Figures 2 and 3 were derived. By calculating $\frac{\text{(d) at 582 m}\mu}{\text{(d) at 544 m}\mu}$ and $\frac{\text{(d) at 582 m}\mu}{\text{(d) at 564 m}\mu}$ of an extract containing only oxymyoglobin and metmyoglobin, the percentages of these 2 compounds in the extracts are obtained from the curves of Figure 4.

If the solution contains only myoglobin and metmyoglobin, from the inspection of Figure 1 it seems logical to calculate

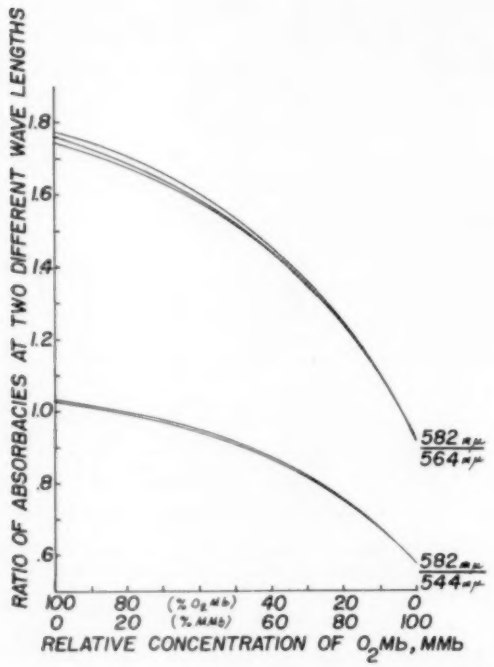

Figure 4. Curves for determination of the relative concentrations of O_2Mb and MMb after measuring the absorbancies at 582 mμ, 564 mμ, and 544 mμ.

(Different curves are due to variations in the measured values of absorbancies at the given wave lengths.)

the ratios for the extract at 484, 505, and 555 mμ because at 484 and 555 mμ, the maximum and minimum of the extinction coefficients of reduced myoglobin and at 505 mμ, the maximum of the extinction coefficients of metmyoglobin appear.

Percentages of metmyoglobin and reduced myoglobin may be determined by the same procedure, using the curves in Figure 5.

Wave lengths chosen for calculating the absorbancy ratios to be used in these determinations represent maximum and minimum values of extinction coefficients for pure solutions of the single compounds concerned, but do not represent the exact maximum and minimum values of the extinction coefficients of solutions containing mixtures of the compounds. In solutions of the latter type, maximum and minimum values of extinction coefficients occur at different wave lengths from those of the maximum and minimum values of single compounds in solution; nevertheless, since the chosen wave lengths actually are those of the maximum and minimum effects of the individual compounds being measured, it is thought best not to change the wave lengths used from those chosen on the basis of the curves of Figure 1.

For determining the relative concentrations of myoglobin derivatives either by the Lemberg and Legge method or by the method of "ratio of absorbancies," no advance knowledge of the total concentration of myoglobin compounds in the extract is necessary. The former method determines the total concentration as the sum of the concentrations of the 3 derivatives. The latter method determines only percentage relationships without determining actual concentrations. In this method, the value of the ratio of absorbancies, being equal to the value of the ratio of the millimolar extinction coefficients, is independent of the total concentration of the compounds. The latter fact appears to be verified by the relatively close agreement among the ratios of absorbancies obtained for four extracts prepared by procedures which were intentionally varied to produce different concentrations of myoglobin pigments in the different extracts. The absorbancy values show that these concentrations did actually vary. The proposed procedure, in which the ratios are used, not only is simple in design and operation but also has the advantage of speed, and perhaps also of accuracy, over methods which require the use of chemical analyses. Chemical analyses, applied to myoglobin compounds, are regarded as having a comparatively low degree of accuracy. Experiments were designed with the objective of either validating or disproving this hypothetical method of determining relative concentrations of myoglobin derivatives.

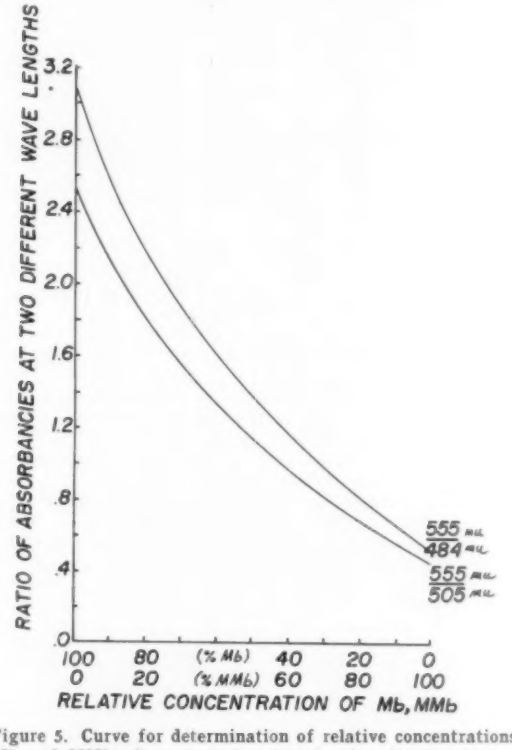

Figure 5. Curve for determination of relative concentrations of Mb and MMb after measuring the absorbancies at 555 mμ, 505 mμ, and 484 mμ.

EXPERIMENTS TO TEST THE METHOD

In experiments to test the absorbancy ratio method, all samples were packed in cans. About 70 g. of ground lean meat constituted a sample, which was put into a can with a sterile spoon. With the back of a spoon, the meat was packed very tightly and a smooth surface was obtained. This packing and smoothing of the surface had a three-fold purpose:

(1) As much as possible, air was excluded from pores between tissues.

(2) The outline of the ground sample was made to resemble that of a cut sample.

(3) A smooth surface facilitated the removal of a layer of meat 2–3 mm. thick without including tissue of the inner portion having a different color than the meat at the surface.

Extracts were made as will be described.

Absorbancy measurements were made with a Beckman Model D. U. Quartz Spectrophotometer. Matched square cuvets of optical thickness of 0.997 ± 0.002 cm. were used throughout.

Meat extracts used in absorbancy ratio method. In making absorbancy measurements on myoglobin compounds, extracts of the compounds must be used; therefore, when the purpose is to determine the relative concentrations of the compounds

in meat, care must be taken during extraction to ensure that myoglobin derivatives are present in the extracts in the same relative concentrations as in the meat.

Attempts were made to obtain meat juice by pressing meat, wrapped in cheese cloth, in a Carver Hydraulic Press under 1–5 tons/in.^{2} of pressure. The method was abandoned because of the following difficulties:

1. To express enough juice for experiments, 20–25 g. of meat was needed. If only the surface layer of a meat sample were used, the size of the sample needed to provide 20–25 grams of meat would be impractical.
2. The expressed juice was cloudy and could not be cleared by filtration.
3. The concentration of myoglobin compounds in meat juice was high, and the dilution necessary increased the cloudiness of the juice.
4. The expressed juice of fat samples always contained fat.
5. It is believed that the sulphur-containing compounds present in the cheese cloth could change the relative concentrations of the myoglobin compounds during pressing.

Successful attempts were made to quantitatively extract meat pigments by methods which proved impractical and tedious because of the requirement that the oxygen tension be kept at a low level. These methods also were abandoned and will not be described.

Attempts were made to extract the pigments with various organic solvents, with acidulated water, and with salt water, but unsatisfactory results were obtained. Distilled water extracted more pigments than any other solvent. Clear extracts were obtained with distilled water, whereas buffered solutions resulted in cloudy extracts, which could not be clarified either by centrifuging or by filtering.

As is well known, the rate of change of myoglobin and most of its derivatives, when in contact with free oxygen, varies with the temperature. As a step in working out an extraction procedure, tests were made to determine whether or not variation in the temperature at which extractions with water were made and in the time required for the extraction procedure had an effect upon the results obtained with absorbancy ratio determinations of the proportions of the myoglobin derivatives. These tests, based on the curves of Figure 4, which are used when reduced myoglobin is assumed to be absent, gave the results shown in Table 2. On the presumption that the absorbancy ratio method is valid, these results, though somewhat erratic, were still sufficiently consistent to indicate that the composition of the pigments changed during a prolonged extraction operation.

A procedure was adopted which gave reproducible results from the standpoint of the proportions of myoglobin derivatives present. A short extraction period with about 25 ml. of cold water for 5 to 10 grams of meat was used.

Maintenance of a constant pH value is important since myoglobin derivatives are sensitive to pH changes. Addition of a phosphate or a phthalate buffer after extraction was completed produced no evidence of colloidal particles; therefore, this method was used to control the pH value of the extract. Measurements of pH were made with a Beckman pH Meter, Model G.

Extraction procedure. With fresh meat, the meat was ground or chopped very fine, and 5–10 g. were transferred to an Erlenmeyer flask. In "canned" samples a layer 2–3 mm. thick was scraped from the top surface of the meat and placed in an Erlenmeyer. Twenty-five ml. of chilled (45° F.) distilled water was added, the flask stoppered, and shaken vigorously for one minute. The stopper was then removed and the contents filtered through Whatman No. 1 filter paper, which had been washed with distilled water. The first 2–3 ml. of filtrate was discarded and the next 6–7 ml. was transferred to a small beaker. The pH of this extract was adjusted to 5.9–6.1 by the addition of sodium acid phosphate. If the filtrate was not clear, it was refiltered.

Check of extinction coefficient values. Successful use of the absorbancy ratio method depends upon having accurate data on the extinction coefficients of the myoglobin derivatives.

Data obtained from the literature are conflicting. Most data are based on information obtained using horse heart myoglobin. Preparation of pure myoglobin from muscles of beef, lamb, and pork is reported to be quite difficult.

An extract was prepared from freshly cut beef, which had been hung for 3 days. Three cuvets, A, B, and C, were filled with this extract. A trace (less than 1 mg.) of sodium dithionite ($Na_2S_2O_4$), and potassium ferricyanide [$K_3Fe(CN)_6$], were added to cuvets B and C, respectively. The purpose of the sodium dithionite was to reduce all myoglobin derivatives present in the meat extract to reduced myoglobin. The purpose of the potassium ferricyanide was to oxidize all myoglobin derivatives present in the meat extract to metmyoglobin.

Extinction coefficients of all 3 solutions were determined at wave lengths at which maxima and minima of the extinction coefficients of myoglobin, oxymyoglobin, and metmyoglobin appear in Figure 1. Ratios of the determined maximum to the determined minimum extinction coefficient of each of the 2 derivatives, myoglobin and oxymyoglobin, in the extracts prepared as described above, agreed with the determinations of both Theorell *(6)* and Bowen *(2)* and the value of the corresponding ratios for metmyoglobin agreed with the determinations of Bowen *(2)* (Figure 1). Similar results were obtained when the procedure was repeated using meat from a second steer. Table 3 shows the values obtained in comparison to values calculated from the data of Theorell *(6)* and Bowen *(2)*.

Results (Table 3) paralleled Bowen's data more closely than Theorell's.

TABLE 2

Relative concentrations of myoglobin compounds responsible for the original color of meat, as indicated by the absorbancy ratio method

Code No. of run	Type of meat	Age of meat[1]	Meat held before extraction		Extract held before absorbancies were determined		% of O_2Mb	% of MMb
			Time	Temp. °F.	Time	Temp. °F.		
		days	*hours*		*minutes*			
Y	pork lean	5	2	45°	15	70°	96	4
Z	pork lean (frozen)	30	2	45°	15	70°	72	28
AA	pork lean	5	2	45°	15	70°	90	10
CC	beef lean	12–18	2	70°	15	70°	80	20
DD	beef lean	5	3	70°	15	70°	61	39
DD	beef lean	5	3	70°	75	70°	50	50
EE	beef lean	5	2	70°	15	70°	80	20
FF	beef lean	5	2	70°	15	70°	80	20
II	lamb lean	5	2	70°	10	70°	90	10
MM	beef lean	5–15	3–4	70°	5	70°	60	40
MM	beef fat	5–15	3–4	70°	5	70°	78	22
MM	pork lean	5–15	3–4	70°	5	70°	71	29
MM	lamb lean	15	3–4	70°	5	70°	93	7
NN	beef lean	4	2	45°	5	70°	100	0
NN	beef lean	4	2	45°	10	70°	97	3

[1] Days held in wholesale cuts.

TABLE 3

Ratios of absorbancies of myoglobin derivatives at two different wave lengths

Ratio	Theorell (6)	Bowen (2)	Meat extract of these experiments
$\frac{E_{mM} \text{ at } 582\ m\mu}{E_{mM} \text{ at } 544\ m\mu}$ for pure O_2Mb	1.025	1.025	1.024–1.025
$\frac{E_{mM} \text{ at } 582\ m\mu}{E_{mM} \text{ at } 564\ m\mu}$ for pure O_2Mb	1.72	1.77	1.74 –1.78
$\frac{E_{mM} \text{ at } 555\ m\mu}{E_{mM} \text{ at } 484\ m\mu}$ for pure Mb	.32	.324	.308– .31
$\frac{E_{mM} \text{ at } 505\ m\mu}{E_{mM} \text{ at } 590\ m\mu}$ for pure MMb	2.5	3.26	3.1 –3.2

Procedure for spectrophotometric determination and calculation. Tests to evaluate the absorbancy ratio method of determining the relative concentrations of myoglobin compounds were made with the use of Figure 4 for extracts which were in contact with molecular oxygen and with the use of Figure 5 if molecular oxygen was absent. To exclude oxygen, the cuvets were sealed. A reference cuvet filled with distilled water was included in each test.

Absorbancies of extracts in contact with molecular oxygen were measured at 544, 564, and 582 mμ. The values of $\frac{(d) \text{ at } 582\ m\mu}{(d) \text{ at } 544\ m\mu}$ and $\frac{(d) \text{ at } 582\ m\mu}{(d) \text{ at } 564\ m\mu}$ were calculated and the relative concentrations of oxymyoglobin and metmyoglobin were determined from the curves in Figure 4. Absorbancies of extracts not in contact with molecular oxygen were measured at 484, 505, and 555 mμ. Values of $\frac{(d) \text{ at } 555\ m\mu}{(d) \text{ at } 505\ m\mu}$ and $\frac{(d) \text{ at } 555\ m\mu}{(d) \text{ at } 484\ m\mu}$ were calculated and the relative concentrations of myoglobin and metmyoglobin were determined from the curves of Figure 5.

The first tests, made with meat from Runs CC, DD, EE, and FF (previously described) involved the question of whether or not hemoglobin derivatives were present in the meat. According to reports in the literature, meat from an animal that is properly bled contains only myoglobin derivatives and should not contain any appreciable amount of hemoglobin derivatives. From the data of Austin and Drabkin *(1)*, on the extinction coefficients of hemoglobin compounds, curves were constructed corresponding to the myoglobin curves of Figures 2 and 4. For the purpose of a test, it was assumed that, in Runs CC and DD, the meat extract contained only methemoglobin and oxyhemoglobin, and that in Runs EE and FF, it contained hemoglobin, methemoglobin, and oxyhemoglobin. Using the absorbancy ratio curves constructed for hemoglobin compounds, the concentration data on methemoglobin shown in Table 4 were calculated.

Wide discrepancies between the values obtained from 2 different ratios for the same extract are interpreted to indicate that quantities of hemoglobin compounds present are almost negligible. Conversely, on the assumption that methemoglobin was not present in the extracts, the erratic results in this test for methemoglobin would be construed to show that the absorbancy ratio method goes askew when absorbancy ratio curves inapplicable to the compounds present are used.

Correction for cloudiness of the extract. In spite of the precautions observed, cloudy extracts were sometimes obtained. Pork presented the greatest difficulty, although beef and lamb sometimes produced cloudy extracts. To correct for cloudiness the following method was devised:

Two suspensions of Bentonite were prepared by adding a trace of the clay to distilled water and shaking vigorously. One solution contained more Bentonite than the other. Cuvets were filled with these solutions and their absorbancies determined at wave length 730 mμ and at 6 wave lengths used in calculating the concentrations of the colored compounds, 484, 505, 544, 555, 564, and 582 mμ.

If:

d = Absorbancy of clear extract at any wave length

TABLE 4

Per cent methemoglobin indicated by two different absorbancy ratios for extracts from meat from properly bled animals

Run	Days of storage	%	MHb
CC	0	55	68
CC	1	74	80
CC	4	69	74
CC	8	47	59
DD	0	73	78
DD	1	82	85
DD	6	97	100
DD	7	93	96
EE	3	80	48
EE	7	55	87
EE	10	66	90
EE	28	92	98
FF	0	57	45
FF	1	36	30
FF	6	71	67

a = Absorbancy due to cloudiness in cloudy extract at any wave length

b = Absorbancy due to color in cloudy extract at any wave length

e = Absorbancy of cloudy extract at any wave length

By definition

$$e_{730} = b_{730} + a_{730} \tag{6E}$$

$$a_n = e_n - b_n; \tag{7E}$$

Subscripts represent the wave lengths at which the absorbancies were determined and "n" symbolizes any wave length. For 2 solutions, both containing the same amount of color compound, one solution being clear, the other cloudy, it is assumed that

$$b_n = d_n \tag{8E}$$

Cloudiness alone was assumed to account for the absorbancy values obtained in the Bentonite suspensions; therefore, the symbol "a" was taken to represent the absorbancy of a Bentonite suspension. The actual absorbancy values of the 2 Bentonite suspensions at any wave length were different, but for each suspension the values of the ratios, $\frac{a_{582}}{a_{730}}$, $\frac{a_{544}}{a_{730}}$, $\frac{a_{555}}{a_{730}}$, $\frac{a_{544}}{a_{730}}$, $\frac{a_{505}}{a_{730}}$, and $\frac{a_{484}}{a_{730}}$ were found to be 1.3, 1.35, 1.4, 1.45, 1.60, and 1.65, respectively. It was therefore assumed that these ratio values would hold for every intensity of cloudiness.

The ratio is represented by the symbol K_n, where "n" represents the wave length of the numerator.

By definition

$$\frac{a_n}{a_{730}} = K_n$$

and therefore, the correction due to cloudiness, (or absorbancy due to cloudiness) at any wave length is

$$a_n = K_n a_{730} \tag{9E}$$

In a cloudy extract containing colored compounds, a_n is the component of the absorbancy value which is produced by the cloud attribute alone. This, combined with the absorbancy value of the colored compound in clear solution, makes up the absorbancy value e_n of the cloudy solution. Thus, the value of a_n is independent of the relative concentrations of myoglobin derivatives in the extract and $b_n = e_n - a_n$ [see eq. (7E)].

For a cloudy extract which contains only reduced myoglobin, from eq. (6E),

$$e_{r730} = a_{730} + b_{r730} \tag{6E}$$

$$e_{r555} = a_{555} + b_{r555} \tag{10E}$$

The subscript "r" indicates that the extract contains only reduced myoglobin. The subscript "r" is not used with "a"

because the value of "a" is independent of the concentration of colored compounds in the solution.

Data obtained by Bowen *(2)* indicate that the millimolar extinction coefficients of myoglobin in clear solutions at 555 and 730 mμ are 12.9 and 0.37, respectively. Therefore, according to Bowen, the value of $\frac{\text{(d) at 730 m}\mu}{\text{(d) at 555 m}\mu}$ of a clear solution containing only myoglobin is equal to

$$\frac{.37}{12.9} = 0.028 \qquad (5E)$$

Combining equations (5E) and (8E)

$$b_{r730} = .028\ b_{r555} \qquad (11E)$$

Combining the equations (11E) and (6E)

$$a_{730} = e_{r730} - .028\ b_{r555} \qquad (12E)$$

Using the value of b_{r555} of equation (10E) in equation (12E)

$$a_{730} = e_{r730} - .028\ (e_{r555} - a_{555}) \qquad (13E)$$

Combining equations (13E) and (9E)

$$a_n = K_n\ [e_{r730} - .028\ (e_{r555} - a_{555})]$$

and

$$a_{555} = K_{555}\ [e_{r730} - .028\ (e_{r555} - a_{555})]$$

$$a_{555} = K_{555}\ e_{r730} - .028\ K_{555}\ e_{r555} + .028\ K_{555}\ a_{555}$$

$$(1 - .028\ K_{555})\ a_{555} = K_{555}\ (e_{r730} - .028\ e_{r555})$$

$$a_{555} = \frac{K_{555}}{1 - .028\ K_{555}}\ (e_{r730} - .028\ e_{r555}) \qquad (14E)$$

It as indicated in equation (9E) that

$$\frac{a_n}{a_{730}} = K_n \qquad (9E)$$

or

$$\frac{a_{555}}{a_{730}} = K_{555} \text{ and } \frac{a_{562}}{a_{730}} = K_{562}$$

Therefore

$$\frac{\frac{a_{555}}{a_{730}}}{\frac{a_{562}}{a_{730}}} = \frac{a_{555}}{a_{562}} = \frac{K_{555}}{K_{562}} \qquad (15E)$$

From eqs. (9E) and (15E), $\quad a_n = \frac{a_{555}\ K_n}{K_{555}} \qquad (15E')$

Combination of (14E) and (15E'), with $K_{555} = 1.4$ (see page 70) gives

$$a_n = \frac{1}{0.960}\ K_n\ (e_{r730} - 0.028\ e_{r555})$$

$$a_n = 1.04\ K_n\ (e_{r730} - 0.028\ e_{r555}) \qquad (16E)$$

Values of K_n for 6 wave lengths are shown above.

Formula (16E), representing the absorbancy resulting from cloud, applies only under the condition that all myoglobin derivatives are converted to reduced myoglobin before e_{r730} and e_{r555} are determined.

Equations similar to (14E) and (16E), but with different constants, may be derived for use when all myoglobin derivatives are converted to either oxymyoglobin or metmyoglobin. Myoglobin derivatives are converted to reduced myoglobin for the following reasons:

1. Myoglobin derivatives are easily reduced with dithionite to reduced myoglobin.

2. Dithionite is colorless; therefore, if an excess is added to the extract, no color error is introduced. Excesses of oxidizing agents like potassium ferricyanide introduce a color error into the extracts.

Wave lengths 555 and 730 mμ are those of the maximum and minimum, respectively, in the absorption spectrum of myoglobin in the visible range. In the above method, it was found that the greater the difference between the absorbancies at the 2 wave lengths, the more accurate were the results.

Procedure for and example of cloudiness correction. The absorbancies (e) of the cloudy extract are measured at the seven specified wave-lengths 730, 582, 564, 555, 544, 505, and 484 mμ. A trace of dithionite is added to convert all myoglobin derivatives to reduced myoglobin. Absorbancies of the extract after the addition of dithionite are determined at 555 and 730 mμ (e_{r555} and e_{r730}.) The absorbancy due to cloudiness at 555 mμ (a_{555}) is determined using equation (14E) and the value $K_{555} = 1.4$.

The absorbancy due to cloudiness at any wave-length at which the absorbancy of the cloudy solution was measured is determined using equation (15E), using the appropriate K_n value from the list on page 70. At any wave-length, the calculated a_n value is subtracted from e_n to obtain b_n, or the absorbancy due to color.

An arbitrary criterion for evaluating the absorbancy ratio method of estimating relative concentrations of myoglobin compounds was adopted. The difference between the percentage concentration values for a myoglobin derivative, indicated by any 2 absorbancy ratios for an extract, as, for example, the ratios at $\frac{555\ \text{m}\mu}{484\ \text{m}\mu}$ and $\frac{555\ \text{m}\mu}{505\ \text{m}\mu}$, respectively (see Figure 5), must not exceed 3 numerical units. Use of the correction formula for cloudy solutions showed that if $\frac{a_n}{b_{rn}} > 0.1$, the results obtained from 2 different absorbancy ratios for per cent concentration of a given myoglobin derivative relative to the total concentration of myoglobin derivatives in the solution after the correction had been applied would differ by more than 3 numerical units. Therefore, if $\frac{a_{555}}{b_{r555}} > 0.1$, a correction for cloudiness of a solution should not be made because too great an error is introduced, and the cloudy solution should be discarded. This test of the correction may be applied as soon as the value of a_{555} has been determined by equation (14E), since $\frac{a_{555}}{b_{r555}} = \frac{a_{555}}{e_{r555} - a_{555}}$.

The following example illustrates the correction for cloudiness. The absorbancies of the cloudy extract are first determined. These may be:

$e_{562} = .298$

$e_{564} = .183$

$e_{544} = .281$

A trace of dithionite is added to the extract and the absorbancies at 555 and 730 mμ read:

$e_{r555} = .314$

$e_{r730} = .028$

From equation (14E)

$a_{555} = 1.04 \times 1.4\ (.028 - .028 \times .314)$

$a_{555} = 1.04 \times 1.4 \times .019$

$a_{555} = .028$

then

$$\frac{a_{555}}{e_{r555} - a_{555}} = \frac{.028}{.314 - .028} = \frac{.028}{.286} < 1/10$$

Therefore this method of correction could be applied from equation (15E') and the value of a_{555}.

$$a_{562} = \frac{.028 \times 1.3}{1.4} = .026$$

$$a_{564} = \frac{.028 \times 1.35}{1.4} = .027$$

$$a_{544} = \frac{.028 \times 1.45}{1.4} = .029$$

Absorbancy due to the color:

$$d_{582} = b_{582} = c_{582} - a_{582} = .298 - .026 = .272$$

$$d_{564} = b_{564} = c_{564} - a_{564} = .183 - .027 = .156$$

$$d_{544} = b_{544} = c_{544} - a_{544} = .281 - .029 = .252$$

EFFECTS OF VACUUM PACKING UPON ABSORBANCY RATIO RESULTS

The degree of correlation which exists between the results of the absorbancy ratio method and some factors known to influence color in fresh meat should give some indication of the validity of the absorbancy ratio procedure as an analytical tool. Three such factors, extensively covered in the literature, are (1) storage time, (2) bacterial flora, and (3) free oxygen. All of these are widely recognized as exerting an influence on the color of meat, although there does not exist uniformity of viewpoint as to their effects on color. With the use of the methods of extraction and calculation which have been described, tests were made to show how variation in each of these factors affects the results of absorbancy ratio determinations of the relative concentrations of fresh meat color compounds. Then, such correlations having been found to exist, some absorbancy ratio determinations were made on muscles taken from different animals. First, the tests applying to the storage factor:

Duplicate samples of ground lean meat similar to those used in other phases of this project were tested on specified days during the storage period. On the various removal days, the meat was in contact with air for about 5 minutes prior to the recording of the observed color and to the extracting of the myoglobin compounds. On the initial day of storage, the meat remained in contact with air for the varying lengths of time (Table 2).

Figures 6, 7, and 8 show the effects of different storage conditions, and Table 5 contains a typical calculation. The curve for beef, shown in Figure 6 was constructed from the data in Table 5. Figures 6 and 7 show the changes in the relative concentrations of metmyoglobin and oxymyoglobin in lean beef, pork, and lamb sealed in cans and stored at 40° F. Samples shown in Figure 5 were sealed under 27 inches of vacuum; and those in Figure 7 were sealed in air at

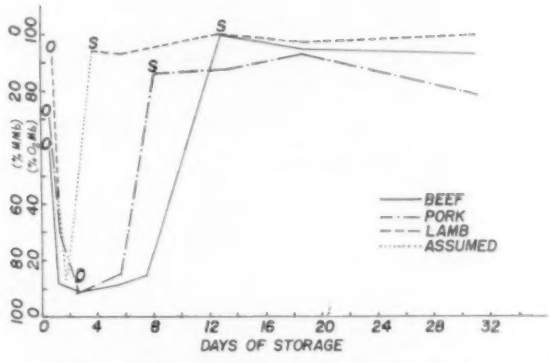

Figure 6. Proportions of heme derivatives in meat which had been stored in sealed cans under vacuum. Determined by the absorption ratio method.

atmospheric pressure. Figure 8 contains composite data representing the beef samples shown in Figures 6 and 7, along with data on beef fat, packaged and stored under the asme conditions as the lean.

These curves show characteristics similar to those obtained in other divisions of this investigation on similar samples tested for redness in the Hunter Color and Color Difference Meter.

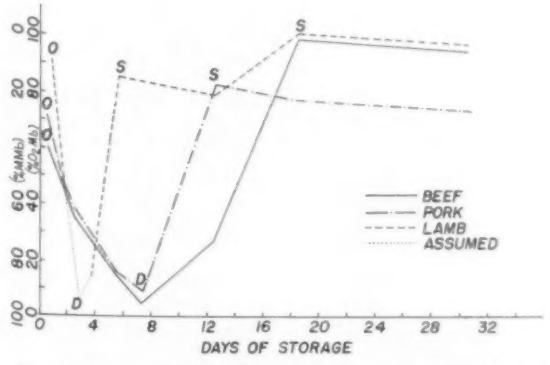

Figure 7. Proportions of heme derivatives in meat which had been stored under atmospheric pressure in sealed cans. Determined by the absorption ratio method.

TABLE 5

Tabulation of the steps in calculation of the relative concentrations of oxymyoglobin and metmyoglobin in beef lean stored under vacuum as shown in Figures 6 and 8

Day of storage	0	1	2	5	7	12	18	31
(d) at 544 mμ	.520	.301	.224	.137	.152	.315	.291	.424
(d) at 564 mμ	.397	.177	.133	.0825	.091	.182	.170	.244
(d) at 582 mμ	.491	.205	.143	.940	.106	.3225	.295	.430
(d) at 582 mμ / (d) at 564 mμ	1.6	1.16	1.08	1.14	1.16	1.77	1.74	1.76
(d) at 582 mμ / (d) at 544 mμ	.945	.680	.64	.69	.70	1.024	1.013	1.014
% O_2Mb	60%	14%	7%	13%	14%	98%	89%	95%
(Figure 4)	60%	11%	9%	12%	13%	98%	88%	94%
% MMb	40%	86%	93%	87%	86%	2%	11%	5%
(Figure 4)	40%	89%	91%	88%	87%	2%	12%	6%

These data were obtained from the curves of Figure 4. The assumption that myoglobin was absent seems to have been confirmed by the close agreement that is shown between the results with 2 different absorbancy ratios (Table 5).

COMPOSITION OF THE ORIGINAL RED COLOR OF MEAT

Determinations which yielded the data on wholesale cuts of meat shown in Table 2 gave similar close agreement between results obtained with 2 different absorbancy ratios (see Figure 4) to that shown in Table 5; therefore, the data of Table 2 were accepted as indicating that reduced myoglobin was absent in the extracts used in the determinations of the original red color.[d] Since the data in Table 2 indicate that the highest percentages of oxymyoglobin were found in meat which was held only 4 days, it was felt that these data show that the percentage of metmyoglobin increases with longer storage of the meat. A similar effect in pronounced degree is shown to accompany the holding of extracts in contact with air before the absorbancies were determined. Data on lean beef indicate that the relative concentration of oxymyoglobin decreased almost linearly with time when the meat extract was held at room temperature in contact with air for periods up to 75 minutes.

CORRELATION BETWEEN OBSERVED COLOR AND RELATIVE CONCENTRATION OF METMYOGLOBIN

To one observer,[e] there appeared to be a clearly perceptible correlation between observed color and the relative concentration of metmyoglobin in the meat represented in Figures 6, 7, 8. The color of beef and lamb was dull red, greyish red, reddish grey, and grey or brown when the determinations by the absorbancy ratio method indicated that the meat extract contained, respectively, 20–30%, 40–50%, 60–70%, and 80% or more metmyoglobin (per cent oxymyoglobin plus per cent metmyoglobin = 100%). For pork, the color changed from pink to grey and it was not easy to establish a standard such as above. This subjective correlation, of course, is arbitrary.

The curves in Figures 6, 7, and 8 appear to corroborate a phenomenon which has been noted widely by both scientific and industrial workers that discoloration appears faster in low oxygen tension than at higher oxygen tension.

Observations on the "second red color." It was observed that the color of stored meat changed when the meat came into contact with air. Therefore, it should be reemphasized that observations on meat color and extractions of the color compounds were made after the meat had been in contact with air for some time. Contact with air resulted in removal of reduced myoglobin so that the procedures involving only oxymyoglobin and metmyoglobin could be used.

[d] Table 2 does not show the data from both absorbancy ratios.

[e] This observer was the worker who performed these tests.

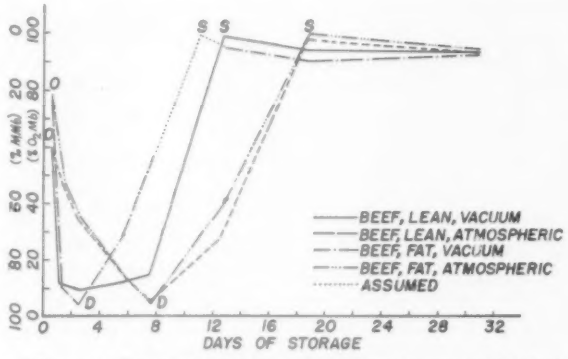

Figure 8. Proportions of heme derivatives in meat which had been stored in sealed cans under vacuum and atmospheric pressure. Determined by the absorption ratio method.

The color of the surface layer of meat stored in sealed cans for 12 days under vacuum or 18 days under atmospheric pressure was purple red at the time the can was opened. The "second red" color seemed to be the color which the surface tissue assumed after it came into contact with air. The bottom surface of the meat which was in close contact with the can surface (no air present) became purple red in a shorter period than the top surface. A series of preliminary experiments indicated that the color of meat extract stored at room temperature in tightly sealed containers (test tubes tightly stoppered) changed from red to greyish brown and finally purple. These observations seem to indicate that myoglobin is produced in stored meat and in stored meat extract.

The color of a sample of freshly cut meat and the color of stored meat (after the "second red" color appeared) changed from purple red to bright red within one or two minutes after the meat tissue was placed in a beaker of water. In air an identical sample required from 5 to 20 minutes to become bright red. No explanation can be offered for the difference between the rate in air and the rate in water.

The composition of the "second red" color. S symbols in Figures 6, 7, and 8 indicate the points of return of the red color, or the appearance of the "second red" color; D symbols, the points of deepest grey or brown color. It appears that, after the meat comes into contact with air, the composition of the "second red" color is about 80–100% oxymyoglobin and 20–0% metmyoglobin.

Results plotted in Figure 8 indicate that the amount of vacuum in the can had a much less pronounced effect upon the rate of return to red color than upon the rate of prior disappearance of the red color.

EFFECT OF MICROORGANISMS AND FAT ON THE RATE OF COLOR CHANGE

The effect of microorganisms and fat on the rate of color change of the pigments of stored meats and meat extracts was studied. Aseptically handled cuvets containing filtered (cuvets A and B) and nonfiltered

(cuvet C) water extracts of meat were used. Cuvet A contained also an aseptically prepared piece of fat meat tissue. After sealing with stop-cock grease, the cuvets were placed in a constant temperature box at 95° F. For each absorbancy measurement, the cuvets were out of the constant temperature box for about 10 minutes.

Calculated relative concentrations of myoglobin derivatives in cuvets A, B, and C, by the absorbancy ratio method, are plotted against time in Figures 9 and 10. Tables 6 and 7 are sample calculations show-

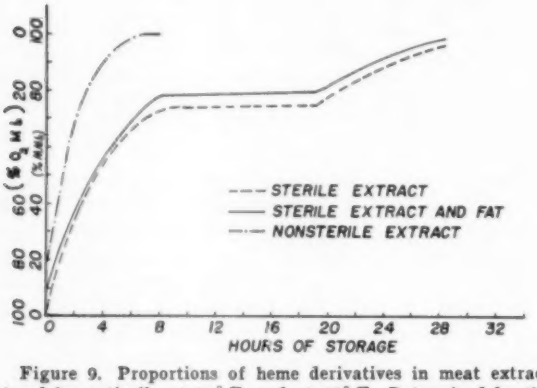

Figure 9. Proportions of heme derivatives in meat extract stored hermetically at 95° F. and at 45° F. Determined by the absorption ratio method. Horizontal lines indicate the time that meat extract was kept at 45° F.

ing how the relative concentrations of myoglobin derivatives were estimated from the absorbancy values of the non-sterile extract. Percentage values in Table 6 were taken from the curves of Figure 4, those in Table 7 from the curves of Figure 5. After the oxymyoglobin had been completely converted to metmyoglobin at 28 hours (Figure 9), the cuvets were continuously held at 95° F. At 43 hours the absorbancy measurements were resumed. Figure 10 shows the relative amounts of metmyoglobin and myoglobin that were determined between the 43rd and 145th hours of storage.

The value of each point in Figure 9 is the average

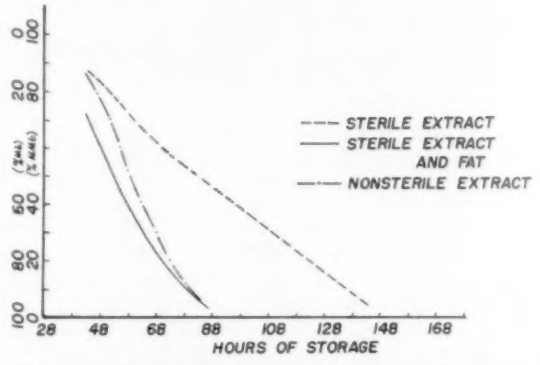

Figure 10. Proportions of heme derivatives in meat extract stored hermetically at 95° F. determined by absorption ratio method. (Continuation from Figure 4).

of the two values obtained from the curves of Figure 4 corresponding respectively to the ratios $\frac{(d)\ 582\ m\mu}{(d)\ 544\ m\mu}$ and $\frac{(d)\ 582\ m\mu}{(d)\ 564\ m\mu}$.

The value of each point in Figure 10 was the average of the two values obtained from the curves of Figure 5 correspoonding to the ratios $\frac{(d)\ 555\ m\mu}{(d)\ 505\ m\mu}$ and $\frac{(d)\ 555\ m\mu}{(d)\ 484\ m\mu}$.

Each absorbancy value used in these determinations was obtained from one sample. In all cases, the percentage values obtained from the two ratios calculated from simultaneously measured absorbancies agreed with each other within 3 numerical units.

When the relative concentration of oxymyoglobin decreased to about 5% and that of metmyoglobin increased to about 95%, the absorbancies of the extract were determined at 484, 505, 544, 555, 564, and 582 mμ. If the relative concentration values of oxymyoglobin, obtained from the two ratios involving the wave lengths 582, 564, and 544 mμ (Figure 4), did not agree with each other within 3 units, it was assumed that no appreciable amount of oxymyoglobin

TABLE 6

Tabulation of the steps in calculation of the relative concentration of oxymyoglobin and metmyoglobin in the non-sterile extract as shown in Figure 9

Hours of storage	0	1 1/3	2 1/5	3 1/5	4 1/3	5 1/5	6 2/3	8
(d) at 544 mμ	.248	.190	.159	.137	.127	.120	.114	.107
(d) at 564 mμ	.143	.111	.096	.086	.076	.074	.069	.063
(d) at 582 mμ	.248	.167	.127	.099	.084	.075	.068	.061
(d) at 582 mμ / (d) at 564 mμ	1.00	1.50	1.32	1.18	1.09	1.01	.96	.92
(d) at 582 mμ / (d) at 564 mμ	1.74	.88	.80	.72	.66	.62	.58	.57
% O_2Mb	88% 88%	45% 43%	26% 26%	15% 15%	8% 9%	5% 5%	2% 1%	0% 0%
% MMb	12% 12%	55% 57%	74% 74%	85% 85%	92% 91%	95% 95%	98% 99%	100% 100%

TABLE 7

Tabulation of steps in calculation of the relative concentrations of myoglobin and metmyoglobin in the non-sterile extract as shown in figure 10

Hours ofstorage	43	48	56	68	73	78	88
(d) at 484 mμ	.150	.132	.117	.0955	.089	0.80	.073
(d) at 505 mμ	.177	.162	.140	.1145	.107	.101	.0945
(d) at 555 mμ	.110	.111	.134	.178	.189	.210	.222
(d) at 555 mμ / (d) at 484 mμ	.627	.71	.957	1.554	1.77	2.08	2.35
(d) at 555 mμ / (d) at 505 mμ	.733	.84	1.145	1.863	2.21	2.63	3.04
% Mb	15% 15%	23% 22%	40% 40%	69% 70%	78% 80%	90% 90%	98% 98%
% MMb	85% 85%	77% 78%	60% 60%	31% 30%	22% 20%	10% 10%	2% 2%

was present. The absorbancies of the extract at 484, 505, and 555 mμ were determined and the relative concentrations of metmyoglobin and myoglobin calculated.

The concentration of free myoglobin is apparently negligible in the extract. Under the conditions of this experiment, it is believed that any newly formed molecules of myoglobin are quickly either oxygenated to oxymyoglobin or oxidized to metmyoglobin.

EFFECT OF ATMOSPHERE ON COLOR

Results shown in Figure 10 seem to corroborate the following propositions advanced by other investigators *(3, 5)*:

(1) In the absence of molecular oxygen the reaction proceeds from metmyoglobin to myoglobin, but no oxymyoglobin is formed.

(2) The rate of reduction is increased in the presence of anaerobic or facultative anaerobic bacteria and fat. (Thus, on the basis of the results in Figure 10, it was speculated that the microorganisms present in cuvet C were either anaerobes or facultative anaerobes.)

Following the experiment represented by Figures 9 and 10, the absorbancies of the extracts stored at 95° F. were determined for 21 days. After one week of storage, the cloudiness of the extracts increased to such an extent that the corrected absorbancy values were not considered reliable. Therefore, between seven and 21 days, only the visual examinations were considered.

During the second week of storage, the extracts in cuvets A, B, and C were purple, indicating that reduced myoglobin predominated. During the third week the color of the extract in cuvet A, which contained a piece of fat, became slightly grey, while the extracts in cuvets B and C remained purple. Some of the myoglobin in cuvet A was apparently oxidized to metmyoglobin.

After 21 days of storage the cuvets were opened. The extract in cuvet A had a sharp sour odor, which may have been due to hydrolytic and some oxidative rancidity. The extracts in cuvets B and C did not have a sour odor. The absorbancies at 582 mμ were determined every two minutes on the extracts from the three cuvets until the highest values were obtained (at 14 minutes). At this point all myoglobin was assumed to have been oxygenated to oxymyoglobin. To accomplish this, molecular oxygen had to penetrate 4 cm. of solution, which was the depth of the liquid in the cuvets. A thin surface layer of myoglobin would require less time for oxygenation.

Absorbancies of the extracts before opening and 14 minutes after opening the cuvets are as follows:

	Before opening	14 minutes after opening
Cuvet A	.116	.120
Cuvet B	.187	.228
Cuvet C	.191	.254

These values indicate that the extract in cuvet C, which was not sterile, had the highest concentration of myoglobin and the extract in cuvet A the lowest myoglobin concentration after 21 days of storage.

One hour after the cuvets were opened the color of the extracts in all cuvets was grey indicating that most of the oxymyoglobin was oxidized to metmyoglobin.

Cuvets were left open in the refrigerator at 45° F. for 60 hours to ensure the complete oxidation of oxymyoglobin to metmyoglobin. The cuvets were then flushed with nitrogen gas, sealed and stored at 78° F. The extract in cuvets B and C became purple in less than one week of storage. The color of the extract in cuvet A remained grey. Apparently most, if not all, the metmyoglobin present in the extracts in cuvets B and C was reduced to myoglobin, while the metmyoglobin in cuvet A remained unchanged, probably due to the presence of oxidizing agents like peroxide.

Subjective observations during and after the storage period of 21 days, as well as the ratio-absorbancy-method calculations during the earlier period of study of the cuvets, indicated that pigments in the extracts closely followed expectations as based upon conventional thinking on the effects of oxidizing and reducing agents under the conditions involved.

RELATIVE MYOGLOBIN CONTENT IN MUSCLE OF DIFFERENT ANIMALS

Distilled water extracts of fat-free muscle tissue of beef, lamb, pork, and veal, to each of which a trace of sodium dithionite had been added, were subjected to determinations of the proportions of reduced myoglobin with the following results:

Type of meat	(d) at 555 mμ
Beef	.617
Lamb	.368
Pork	.161
Veal	.086

Ratios of the absorbancy values are regarded as indicating the relative pigment contents per gram of the muscle tissues of different animals. Since all 4 extracts were prepared and handled in the same manner, it was assumed that the extracted pigments in all 4 instances contained approximately the same relative concentrations of myoglobin derivatives. Under that condition, the absorbancy values would be in direct proportion to the total amounts of pigment compounds in the solutions. Thus, the above data indicate that the relative myoglobin content of beef, lamb, pork, and veal were roughly, 62%, 37%, 16%, and 9%, respectively, or proportionally 7, 4, 2, and 1.

Experiments on the relative content of myoglobin per gram of meat tissue of different animals were conducted only on one sample from each animal. Nevertheless, results obtained are indicative. It is common observation that the color of beef is red while the color of veal is pink.

JUSTIFICATION OF ADOPTED STANDARD OF ACCURACY

Agreement within 3 numerical units between results obtained from 2 different absorbancy ratios was arbitrarily accepted as a criterion of the validity of the assumption that only 2 myoglobin derivatives were present in an extract. A logical jusification for the acceptance of this criterion will now be attempted.

On each removal day one sample of beef lean, beef fat, lamb and pork were used, and the absorbancies of the extracts prepared from each sample were determined at 582, 564, and 544 mμ. The value of each point in Figures 6, 7, and 8 is the average of the values estimated from the ratios $\frac{\text{(d) at 582 m}\mu}{\text{(d) at 564 m}\mu}$ and $\frac{\text{(d) at 582 m}\mu}{\text{(d) at 544 m}\mu}$ and the corresponding curves in Figure 4. The relative concentrations of oxymyoglobin and metmyoglobin in the extract estimated from these two ratios agreed within 3 numerical units proving either that the concentration of any compound other than the above two is negligible or that the absorption spectrum of any other compound present resembles very closely that of either oxymyoglobin or metmyoglobin.

The following values are the millimolar extinction coefficients of myoglobin derivatives given by Bowen *(2)*:

	E_{mM} at 544 mμ	E_{mM} at 564 mμ	E_{mM} at 582 mμ
Myoglobin	11.0	12.2	8.8
Oxymyoglobin	14.6	8.5	15.1
Metmyoglobin	5.3	3.3	3.0

If an extract contains 50% O_2Mb, 50% MMb and 0% Mb., $\frac{\text{(d) at 582 m}\mu}{\text{(d) at 544 m}\mu} = \frac{(50 \times 15.1) + (50 \times 3.0)}{(50 \times 14.6) + (50 \times 5.3)} = .906$

The $\frac{582}{544}$ curve in Figure 4 shows ratio value .906 to correspond to 49.5% oxymyoglobin. The discrepancy is due to error in plotting the curve since the calculated values used for plotting this curve showed that the ratio value of .906 corresponded to 50% myoglobin. If an extract contains 50% MMb, 45% O_2Mb, and 5% Mb, since the absorbancies of the compounds in the solution are cumulative, the measured absorbancies at 582 and 544 mμ (assuming the extinction coefficients of Bowen to be correct) would give the value, $\frac{(50 \times 3) + (45 \times 15.1) + (5 \times 8.8)}{(50 \times 5.3) + (45 \times 14.6) + (5 \times 11)} = .894.$

The $\frac{582}{544}$ curve in Figure 4, in which 0% Mb is assumed, shows that this value corresponds to 46% oxymyoglobin. From these and additional calculations, Table 8 was constructed to show the discrepancies that enter the results for hypothetical solutions containing up to 5% Mb when estimated with the use of the curves of Figure 4, where 0% Mb is assumed.

Table 8 lists percentages of O_2Mb obtained from the curves of Figure 4 corresponding to values of absorbancy ratios calculated by the above formula. These were the absorbancy ratio values that would be expected from the measuring of absorbancies of nine solutions prepared according to the hypothetical formulas shown in columns 2, 3, and 4 of the table. The error in plotting the curves of Figure 4 has been shown to be less than one numerical unit. For solutions containing 2% of myoglobin, percentage values of oxymyoglobin, taken from Figure 4, differ from each other by from 1½ to 7 numerical units and, for solutions containing 5% of myoglobin, values which differ from each other by from 5 to 15 numerical units are obtained.

Results of absorbancy ratio determinations presented herein applying to extracts in which only 2 color compounds were present appear to offer sufficient confirmation of the validity of the method to justify the expectation that consistent results would be obtained with the method when 3 color compounds are involved. The application then would be through the procedural steps presented.

TABLE 8

Percentages of oxymyoglobin corresponding to values of ratios of measured absorbancies according to the curves of Figure 4

Extract number	% Mb	% O_2Mb	% MMb	% O_2Mb (Figure 4) corresponding to ratio values of measured absorbancies		Difference in numerical units
				582 mμ / 544 mμ	582 mμ / 564 mμ	
1	0	90	10	89.5	90.5	1.0
2	2	88	10	89	82	7.0
3	5	85	10	87	72	15.0
4	0	50	50	49.5	50:5	1.0
5	2	48	50	48.5	44	4.5
6	5	45	50	46.0	38.0	8.0
7	0	10	90	10	10	0.0
8	2	10	88	10.5	9	1.5
9	5	10	85	12	7	5.0

On the presumption that the method is valid when 3 compounds are present, it is considered that the hypothetical data in Table 8 proves that when as much as 3 or 4% of a third compound is present, this fact is made apparent by a spread of 3 points or more between values of concentration of one of the other 2 compounds for 2 absorbancy ratios when the absorbancy ratio procedure designed for these other two compounds is used.

Absolute proof of the absorbancy ratio procedure is impossible with present knowledge. Material substantiation of the procedure could be attained by a determination involving chemical analyses for the total concentration of the pigments. However, time limitations precluded making these analyses.

SUMMARY

The development of a method, known as the absorbancy ratio method, for determining the proportions of heme derivatives in meat is described.

Results of calculations by the ratio absorbancy method seem to justify confidence in this method because they corroborate the validity of several phenomena which are endorsed by workers in the field of color in meat.

A close relationship between concentrations of color compounds in meat as indicated by absorbancy ratio determinations and color of fresh meat as observed visually and as determined by the Hunter Color and Color Difference Meter was shown.

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Practical Application of Laboratory Data to Dairy Waste Treatment[a]

(Manuscript received July 5, 1957)

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DISPOSAL OF WASTE is an important responsibility recognized by all branches of the food industry. The use of streams for direct disposal of waste is being restricted since a high percentage of surface waters is used for human consumption, for recreation, and for industrial purposes.

Milk handlers and processors must do their share in the control of pollution. Difficulties in treatment of dairy wastes led the dairy industry to request our Laboratory to make a study looking toward the alleviation of this pollution problem. The high oxygen demand of the dairy waste suggested to us that disposal might be achieved by aeration. Information obtained from this research may be applicable to other food wastes and help in the solution of a vexing problem. Details of our laboratory studies on the aerobic treatment of dairy wastes have been published *(9, 11, 12)*.

Sanitary engineers have shown that such laboratory data are useful in designing plants to treat industrial wastes *(2)*. Some of the principles that evolved from our studies and their application will be discussed in this paper.

The problem of the disposal of liquid wastes from food industries arises because they are considerably stronger than equal volumes of municipal wastes whose B.O.D. is only about 150 p.p.m. The application of aeration as used for the treatment of municipal wastes is usually not effective in the case of strong industrial wastes. A waste of a 1000 p.p.m. solids is actually a dilute solution containing only 0.1% solids and 99.9% pure water. This dilute material is not toxic, but it is excellent food for bacteria and causes disagreeable conditions when improperly handled. The harmful effects result from the lack of oxygen to satisfy the demands of the bacteria in the waste. If we assume that a milk or other food processing plant produces 50,000 gal. of waste a day with a concentration of 1000 p.p.m. solids, it may contain about 420 lb. of solids that will require treatment. About 300 lb. of oxygen will be required for stabilizing this waste; this is the amount of oxygen dissolved in about 4.5 million gal. of water. If this oxygen is not renewed, fish and plant life cannot exist. Natural waterways that have small flow volumes may have difficulty in replenishing the oxygen rapidly enough to maintain aerobic conditions with such concentrated wastes.

RESULTS

In the course of our laboratory studies on the aeration of dairy waste, we found that a synthetic skim milk waste, fed and aerated continuously in laboratory equipment, was easily treated. Analyses showed that about 50% of the skim milk added as waste was completely destroyed and that the remainder was in the sludge *(4)*. Briefly the conversion may be expressed thus:

$$\text{Milk solids} + \text{oxygen} \longrightarrow \text{cells} + CO_2 + H_2O$$

This change occurred so rapidly that, in order to follow the changes, a chemical oxygen demand (C.O.D.) test was used *(10)* rather than the biochemical oxygen demand (B.O.D.) test. Knowing the C.O.D. of milk products, the various B.O.D. values could be approximated: for the skim milk the B.O.D. was 67% of the C.O.D.; for the lactose, 83%; for the whey, 54%; and for the well-aerated sludge, 40% *(13)*. Factors can be established as needed for other items.

Respiration studies were then conducted in a Warburg apparatus which showed that oxygen requirements were high for the first 6 hours when a one-dose addition of 1000 p.p.m. skim milk was acted upon by 500 p.p.m. sludge. Lactose and casein were readily removed from solution and the ratio of CO_2 evolved to O_2 utilized confirmed the idea that the waste was assimilated and oxidized *(3)*. However, complete oxidation did not occur as only about 37.5% of the calculated amounts of oxygen needed for complete combustion were used. Chemical analysis of the sludge gave the empirical formula $C_5H_7NO_2$ if ash, P and S are omitted *(5)*.

The following equations were developed to show the biological oxidation of skim milk which contains about 51% lactose and 37% protein. Complete oxidation of lactose is represented as follows:

$$C_{12}H_{22}O_{11} \cdot H_2O + 12\ O_2 \longrightarrow 12\ CO_2 + 12\ H_2O$$

For simplicity we may take one-twelfth of the lactose molecule and express the oxidation:

$$CH_2O + O \longrightarrow CO_2 + H_2O$$

Cell formation from the sugar may be expressed thus when ammonia is present:

$$5\ CH_2O + NH_3 \longrightarrow C_5H_7NO_2 + 3\ H_2O$$

However, our Warburg studies showed that only 37.5% of the theoretical amount of oxygen was converted to carbon dioxide while the remainder formed cell substances. Therefore, out of 8 available carbons, 3 or 37.5%, were oxidized. This information was written as follows to show cell formation from lactose:

$$3\ O_2 + 8\ (CH_2O) + NH_3 \longrightarrow C_5H_7NO_2 + 3\ CO_2 + 6\ H_2O$$

The utilization of casein for cell formation was also equated. In this case ammonia is liberated:

$$3\ O_2 + C_5H_{12}N_2O_2 \longrightarrow C_5H_7NO_2 + NH_3 + 3\ CO_2 + H_2O$$

Fortunately, the 240 units of sugar and the 184 units of casein required for the above equations are in the same proportion as found in skim milk. Hence, the two equations may be added. The ammonia liberated from the casein is used for lactose assimilation and the reaction remains neutral. The calculated yield, by adding the two equations, is 58%, slightly higher than found in our tests.
Addition gives this:

[a] Presented at the Seventeenth Annual Meeting of the Institute of Food Technologists, Pittsburgh, Pennsylvania, May 13, 1957.

[b] A laboratory of the Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

$$3\ O_2 + 8\ (CH_2O) + NH_3 \longrightarrow C_5H_7NO_2 + 3\ CO_2 + 6\ H_2O$$
$$3\ O_2 + C_5H_{12}N_2O_3 \longrightarrow C_5H_7NO_2 + 3\ CO_2 + H_2O + NH_3$$
$$6\ O_2 + 8\ (CH_2O) + C_5H_{12}N_2O_3 \longrightarrow 2\ C_5H_7NO_2 + 6\ CO_2 + 7\ H_2O$$

When assimilation is finished, the amount of oxygen required drops rapidly and oxygen utilization continues at the very slow rate of unfed cells. This endogenous respiration is represented by the following equation showing that 113 units of cells require 160 units of oxygen for complete combustion:

$$5\ O_2 + C_5H_7NO_2 \longrightarrow 5\ CO_2 + NH_3 + 2\ H_2O$$

The information may be tabulated as follows for waste of 1000 p.p.m. concentration:

Oxygen required for complete oxidation of 1 lb. of skim milk	1.20 lb.
Oxygen needed for assimilation (37.5%)	0.45 lb.
Time required for assimilation depends on cell concentration	
With 500 p.p.m. cells	6 hr.
With 1000 p.p.m. cells	3 hr.
Time decreases with increased sludge concentration.	
Oxygen required per hour depends on cell concentration	
With 500 p.p.m. cells	0.075 lb.
With 1000 p.p.m. cells	0.150 lb.
New cells or sludge produced	0.52 lb.
Oxygen for complete oxidation of new cells	0.75 lb.
Oxygen needed during first 24 hr. varies.	
If 1% oxidation per hr., then 20% per day	0.15 lb.
If 0.5% per hr., then 10% per day	0.075 lb.
Seed cells have respiration requirements.	
Oxygen to oxidize 1 lb. of organic matter	1.42 lb.
Oxygen to oxidize 20% per day	0.29 lb.
Oxygen to oxidize 10% per day	0.15 lb.

INDUSTRIAL APPLICATIONS

Pilot plant investigations conducted at Pennsylvania State University on 10,000 gal. of waste from the college creamery showed the validity of the laboratory data *(7)*. Difficulty was encountered in early studies when the customary aeration devices were used. The supply of available oxygen in solution was insufficient to satisfy the demands shown by the equations. The high oxygen demand of dairy wastes required aeration devices not ordinarily used for weaker wastes. Tests showed that when air was forced through a perforated pipe, only about 1% of the oxygen was dissolved as compared to 2–5% for porous plates. On the other hand, a specific type jet aerator, in which the liquid is pumped and air is sucked in from the atmosphere, showed 17–25% efficiency of oxygen usage *(8)*. Turbine type equipment using compressed air may give higher transfer efficiencies. The jet or aspirator device was satisfactory in treating dairy wastes at the pilot plant *(7)*. The efficiency of this device was increased to 40% when air was supplied to the air inlet under 6 lb. pressure.

A one-tank fill-and-draw treatment plant has been designed for a dairy having about 25,000 gal. of waste daily *(6)*. An average of 95% purification is reported. The tank is large enough to hold more than 34,000 gal. and has an effluent pipe at the 9,000-gal. level which is above the volume occupied by settled cells. This permits draining of 25,000 gal. of treated liquor.

Analyses showed that about 300 lb. of organic matter is present in the waste of this dairy. During the 8 hr. of waste flow, this amounts to 37.5 lb. per hr. and requires 37.5 x 0.45 or 16.9 lb. oxygen per hr. for assimilation. The 300 lb. of milk solids produce 150 lb. of new cells. Since sludge cells may destroy 20% of their own weight in 24 hours and since the new cells should replace old cells, 750 lb. of sludge should be carried in the aerator. By keeping such a balance, it is claimed that little or no sludge accumulates.

From the equations and data, 150 lb. of cells require 213 lb. oxygen or about 9.7 lb. per hr. for 22 hr. Therefore, while the waste is added, oxygen is supplied for assimilation and for endogenous respiration at a total of 16.9 + 9.7 or 26.6 lb. per hour. Then the cells are allowed to settle and the clear supernatant is drained. Aeration of the settled sludge is continued with 9.7 lb. oxygen per hr. until the next morning, when the cycle begins again with addition of fresh waste. When the special size jet aerator is used *(6)* and the liquid is recirculated at 60 gal. per min., each jet can dissolve 1.6 lb. of oxygen per hour from the air that is sucked through the jet. This waste disposal unit is practically automatic and has been in operation 3 years.

Units treating as little as 2,000 gal. of waste have been designed using only 2 or 3 jets. Large continuous flow units treating up to 150,000 gal. of milk processing wastes daily are in operation at Dushore, Pennsylvania, and at Horseheads, New York. The air is supplied at 6 p.s.i. pressure, the sludge is settled in a separate section and is pumped back to the aeration tank. The continuous treatment by jet aeration of 450,000 gal. of citrus waste containing about 3,600 p.p.m. soluble solids is underway at Winter Haven, Florida. The excess sludge in this case is hauled away as fertilizer. It is our understanding that over 60 installations based on the principle of rapid aeration are in use for the treatment of dairy wastes. The same principles of rapid aeration also have been applied to the treatment of other industrial wastes *(1)*.

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Factors Influencing Drained Weight of Canned Clingstone Peaches*

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THE CLINGSTONE PEACH is one of the most important fruits canned in California. During the past few years the annual pack has been about 20 million cases. The grade of canned clingstone peaches is frequently determined in accordance with the standards of the U. S. Department of Agriculture *(11)*. Fill of container and drained weight are important because of their relationship not only to flavor and quality but also to the case yield per ton of fresh fruit. The recommended minimum drained weight is 18½ oz. for peach halves canned in heavy syrup in No. 2½ cans *(11)*.

Factors influencing the drained weight of canned cherries *(1, 2, 4, 15)*, plums *(4)*, berries *(1, 4)*, and a number of other fruits *(9, 13)* have been studied at various research institutes. Detailed information on factors influencing the drained weight of canned yellow clingstone peaches, however, is lacking. Furthermore, yellow clingstone peaches at canning maturity are characteristically firm and differ greatly in texture from other fruits *(8)*. It is not known if this characteristic would cause a difference in drained weight of the canned product. Experiments were therefore designed to determine the influence of maturity, sucrose concentration of the syrup, fill weight, corn syrup replacement for sucrose, and storage time on drained weight and Brix reading of canned yellow clingstone peaches. This paper presents the results of an investigation concerned with these factors.

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EXPERIMENTAL

Clingstone peaches. Two-ton lots of clingstone peaches were harvested from a commercial orchard in 1954 and 1955. Fruits were sorted under a standard light source and graded into three maturities by skin color, i.e., over-ripe (A), optimum (B), and slightly green (C). Sorted fruits were graded for size in a Dudley divergent tubular roller size-grader. Only fruits of 2½ in. to 3 in. in diameter were used in this investigation.

Canning. Samples were halved and pitted with a Filper pitter. The peach halves were peeled in a cup-down peeler with a 1.0% sodium hydroxide solution at 102° C. (214° F.). They were held in the holding section for 30 seconds and then spray-washed with cold water. Fill weights of 18.0, 18.5, 19.0, and 19.5 ± 0.1 oz. of peeled peach halves were weighed into No. 2½ (401 x 411) plain tin cans with lacquered ends. Segments of peach halves were added to reach a desired fill weight. To each can was added 253 ± 2 ml. (10.5 oz. for 40° Brix syrup) of either 0, 20, 30, 40, 50 or 60° Brix sucrose syrup, or 40° Brix syrup in which part or all of the sucrose was replaced by soluble solids from 64 dextrose-equivalent corn syrup. Unless otherwise stated, each No. 2½ can held 19.5 oz. (fill weight) of peach halves at optimum maturity (B) and 253 ml. (10.5 oz.) of 40° Brix sucrose syrup. Cans were sealed in a vacuum closing machine under 15 inches of vacuum, cooked in an Anderson-Barngrover continuous rotary cooker at 100° C. (212° F.) for 31 minutes, and cooked in water in a rotary cooler for 7 minutes.

Analyses of fresh peaches. Twenty peaches were taken at random from each lot and analyzed concurrently with the canning operation for skin and flesh color, pressure test, total acidity, and soluble solids *(7)*.

Determination of drained weight. The canned peaches were stored in the pilot plant at ambient room temperatures of 20° to 35° C. (68° to 95° F.) for various intervals. Unless otherwise stated, 4 cans were selected at random for each sample at desired intervals (over a period of 6 months). Drained weight of each can was determined separately after the peach halves had drained exactly 2 minutes on a tilted 8-mesh screen

(8 in. diameter) as specified in the U. S. Department of Agriculture *Standards (11)*. The average value of the readings was used. Brix reading of the drained fruit was determined after grinding in a Waring blender for 30 seconds. The Brix readings of the syrup and of the mixture of fruit and syrup from the Waring blender were also determined in a Zeiss Opton refractometer.

RESULTS

Chemical analyses and color of the fresh clingstone peaches at 3 stages of maturity are shown in Table 1. On the basis of skin color and Brix/acid ratio, peaches were divided into 3 maturities—over-ripe (A), optimum (B), and slightly green (C). The difference in soluble solids content and acidity among the samples was quite significant. With maturation, soluble solids increased while total acidity decreased *(7)*.

Changes in drained weight and Brix readings during storage. Halford clingstone peaches of optimum maturity were canned in 40° Brix sucrose syrup (Table 1, Sample B) with a fill weight of 19.5 oz. of fruit and 10.5 oz. of syrup for each No. 2½ can. Changes in drained weight and Brix readings are shown in Figure 1. One day after canning, the drained weight

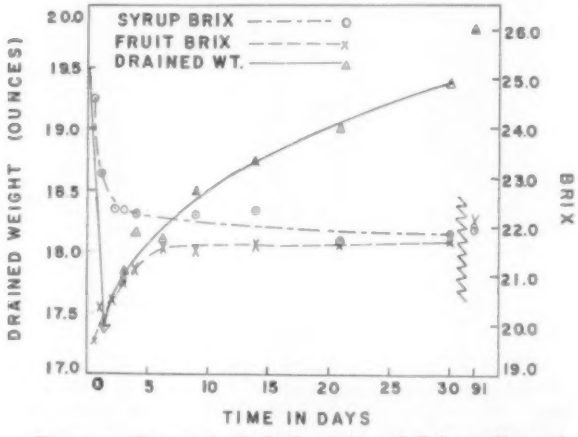

Figure 1. Changes in drained weight and Brix readings of canned Halford clingstone peaches during storage. The peaches were canned at optimum maturity.

was lower than the fill weight; at this stage, it was only 89% of the fill weight. Drained weight increased rapidly during the first 10 days and then slowly as storage time increased. After storage for 30 days, the drained weight was 19.3 oz., a weight retention of 99%. Further storage up to 90 days resulted in an increase in drained weight to 19.8 oz., a weight retention of 101.5%. The Brix readings of the syrup and fruit approached each other rapidly during the 10 days storage, with the Brix of the syrup decreasing while that of the fruit was increasing. They were practically equal after 30 days' storage. The final equilibrium Brix was 22.0°. Apparently, diffusion of sucrose from the syrup into the peach tissue was more rapid during the first week of storage and gradually slowed down as the concentration gradient between the syrup and the fruit decreased.

The experiment was repeated on slightly green Halfords (Table 1, Sample C). Results are shown in Figure 2. In general, the trends for changes in drained weight and Brix

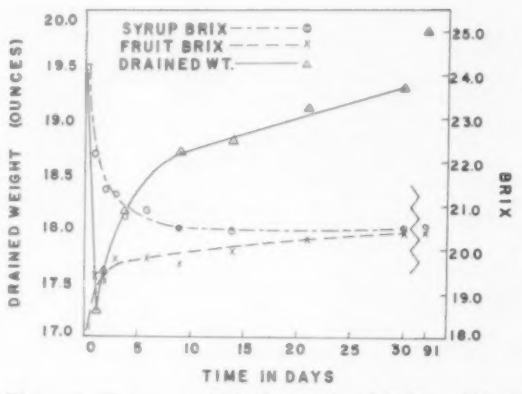

Figure 2. Changes in drained weight and Brix readings of canned Halford clingstone peaches during storage. The peaches were canned slightly green.

readings of the syrup and the fruit followed the same pattern as those of peaches canned at optimum maturity (Fig. 1). However, the equilibrium Brix reading was lower for peaches canned at slightly green maturity. This was caused primarily by a higher Brix reading in peaches at optimum maturity (12.22° Brix) as compared with that of the slightly green fruit (9.52° Brix).

Effect of sucrose concentration on drained weight. The concentration of sucrose in the cover syrup was found to have a pronounced effect on the equilibrium drained weight of the canned product. Figure 3 shows the drained weights of Halfords canned at optimum maturity in different concentrations of sucrose syrup after storage for 6 months. The results were

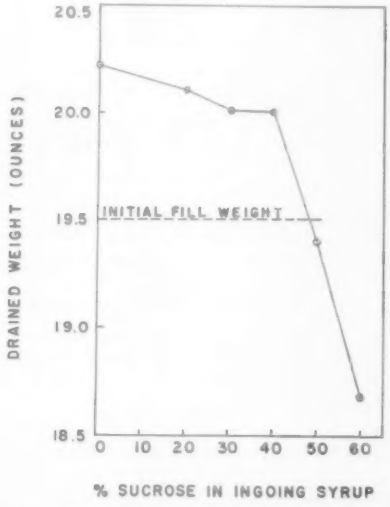

Figure 3. Effect of sucrose concentration of syrup on drained weight of Halford clingstone peaches after equilibrium is reached.

TABLE 1

Physical and chemical properties of clingstone peaches

Sample	Maturity	Approximate Maerz and Paul color plate		Average pressure test, lbs. (5/16 in. plunger)	Brix at 20° C.	pH	Total acid as % citric	Brix/acid
		Skin	Flesh					
A	over-ripe	9L6–9L7	9L5–9L6	6.65	16.13	4.03	0.395	40.8
B	optimum	9L4–9L6	9L4–9L6	8.65	12.22	3.83	0.468	26.1
C	slightly green	18H2 18I1 18J1	9K2 9L2–9L4	8.64	9.52	3.80	0.497	19.2

an average of 12 cans for each sample, with a maximum standard deviation from the mean of 0.3 oz. Samples canned in sucrose syrups of 40° Brix or lower concentrations yielded a drained weight higher than the fill weight. Those canned in 50° Brix or higher concentrations yielded a drained weight lower than the fill weight. Peaches canned in plain water attained the highest drained weight—20.2 oz., a weight retention of 103.7%. For peaches canned in 20, 30, 40, 50, and 60° Brix sucrose syrup, the equilibrium drained-weight retentions were 103.1, 102.6, 102.6, 99.5, and 95.8%, respectively. It is evident that the extremely high sucrose concentration in the cover syrup caused a lower drained weight.

Equilibrium Brix. Syrup "cut-out" requirements for canned clingstone peaches are 24° to 35° Brix for "extra heavy syrup", 19° to 24° Brix for "heavy syrup", and 14° to 19° for "light syrup". The Brix reading at equilibrium may vary with the Brix readings of the fresh peach and the cover syrup as well as the relative weight of fruit and syrup entering the container. One may easily calculate the equilibrium Brix of canned fruit by using an equation based on a material balance between the soluble solids in the fresh peach and the cover syrup and those in the canned product. The relationship between Brix readings of the cover syrup and of the canned product (stored for 6 months), with a fill weight of 19.5 oz. of peaches at optimum maturity for each No. 2½ can, is shown in Figure 4. The result might be used to estimate the sucrose

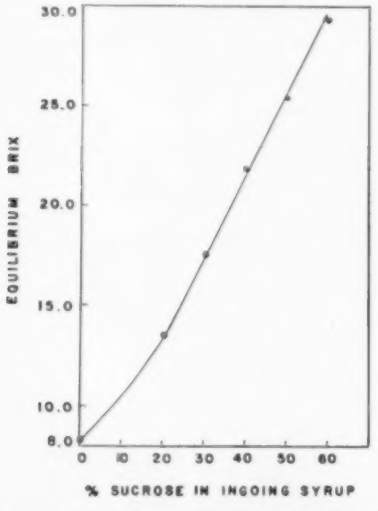

Figure 4. Influence of sucrose concentration in the ingoing syrup on the equilibrium Brix of the canned clingstone peaches (optimum maturity).

concentration in the cover syrup needed to give a certain desired equilibrium Brix. For example, under the conditions of this experiment, when the cover syrup has a Brix reading of 40°, the equilibrium Brix reading found from Figure 4 was 21.50. The theoretical value, as calculated by the material balance of the soluble solids content in the peach and the fruit, should be 21.94° Brix. Thus, the deviation from the theoretical value was 2.01%. This was probably caused by the experimental error in weighing and also the variation of Brix readings among the fresh peaches.

Effect of fill weight on drained weight. Drained weights of canned peach halves are related to the fill weights of the fruit. Results in Table 2 indicate that samples with a higher fill weight yield higher drained weight, and data collected at 1, 30, 90, and 180 days after canning show the same trend. A 90-day period is enough to reach the equilibrium drained weight. A 30-day storage period will achieve a value slightly lower than the final maximum drained weight. If drained weight at 24 hours after canning is used as a reference point, one may predict the drained weight at equilibrium (90 days' storage) by multiplying that value by the factor $\frac{101.5}{88.5}$ or 1.15 (see Table 2). This is applicable only under the conditions described in this experiment. Change in sucrose concentration and volume of the cover syrup will change the factor for calculating drained weight at equilibrium.

In another approach, a semi-log plot of storage time vs. drained weight, originally developed by Weast *(13)*, was made. The results are shown in Figure 5. A linear relationship between storage time and drained weight was obtained. No

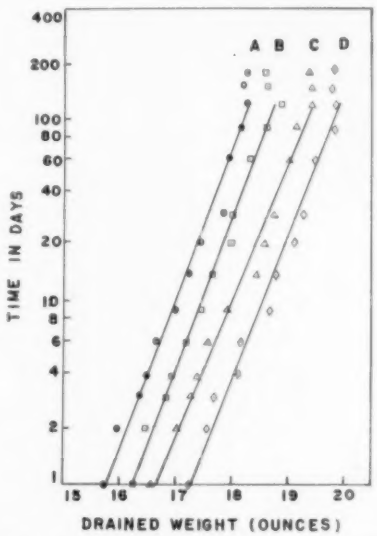

Figure 5. A semi-log plot of time vs. drained weight of canned Halford clingstone peaches. Fill weights of A, B, C, and D series were 18.0, 18.5, 19.0, and 19.5 oz. of peach halves respectively for each No. 2½ can. Ingoing sucrose syrup was 40° Brix.

further increase in drained weight was found after 90 days' storage. The sample with higher fill weight (Sample D, 19.5 oz.) was higher in drained weight than the sample with a lower fill weight (Sample C, 19.0 oz.). The same trends hold for the 18.0 and 18.5 oz. fill weight. Thus, for a desired drained weight at equilibrium, proper fill of the fresh fruit into the can is necessary. To meet the requirement, the average drained weight of the representative samples must have a value equal to, or higher than, the minimum requirement. The fill weights used in this experiment were carefully controlled to get the exact drained-weight data which might be used to predict the expected drained weight for a given fill weight, provided the concentration of the cover syrup is known.

Influence of maturity on drained weight. Differences in drained weight between samples canned at different maturities are shown in Figure 6. All samples were canned in 40° Brix sucrose syrup with a fill weight of 18 oz. for each No. 2½ can. Sample C, canned at slightly green maturity, was a trifle lower in drained weight than Sample B (optimum maturity). Results indicated that, other conditions being equal, the more mature fruit produces a canned product with a slightly higher drained weight than the less mature fruit. The difference was small as compared with the influence of other factors.

Effect of replacement of sucrose by corn syrup. The effect of replacing sucrose with corn syrup solids on the drained weight of canned clingstone peaches is shown in Table 3. The use of 64 dextrose-equivalent corn syrup (acid-enzyme conversion process) to replace partially or entirely the sucrose in the 40° Brix cover syrup produced no significant difference in drained weight of the canned product. The weight retention

TABLE 2

Effect of fill weight on drained weight of Halford clingstone peaches canned in 40° Brix sucrose syrup as halves in No. 2½ cans

Fill weight, oz.	24 hours after canning		30 days after canning		90 days after canning		180 days after canning	
	Drained weight oz.	Weight retention %	Drained weight oz.	Weight retention %	Drained weight oz.	Weight retention %	Drained weight oz.	Weight retention %
18.0	15.75	87.5	17.60	97.8	18.15	100.9	18.30	101.7
18.5	16.25	90.3	18.05	97.5	18.62	100.6	18.60	100.5
19.0	16.65	87.6	18.65	98.2	19.30	101.5	19.40	102.1
19.5	17.25	88.5	19.18	98.3	19.80	101.5	19.80	101.5

was practically the same in all samples which were stored for 6 months after canning. Corn syrup is known to contain some dextrin of high molecular weight. The diffusibility of dextrin and other high molecular weight carbohydrates into clingstone peach tissue is not known. As the drained weight of the canned product was not changed by substituting corn syrup solids for sucrose in the cover syrup, it is likely that the peach tissue is permeable to the soluble solids present in the corn syrup sample used in this investigation.

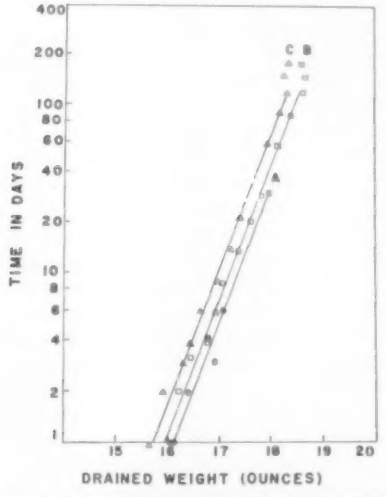

Figure 6. Influence of maturity on drained weight of canned Halford clingstone peach halves (1955 pack). Sample A, over ripe; B, optimum maturity; and C, slightly green. The initial fill weight was 18 oz. for each No. 2½ can. Ingoing sucrose syrup was 40° Brix.

DISCUSSION

Results presented above indicate that fill weight and sucrose concentration in the cover syrup are important factors influencing the drained weight of canned clingstones. In commercial canning, it is not practical for each individual can to have exactly the same fill weight because fruit halves differ in size, and trade practices do not permit using peach segments to maintain a constant fill weight. The only solution is to fill the can to the extent that will yield a product nearest to the desired drained weight. In a No. 2½ can containing 8 or 9 peach halves, a difference in one piece of peach will cause a difference in fill weight of around 2½ oz. In order to compensate for this difference, a variable volume of cover syrup has to be automatically added to maintain a constant headspace, net weight, and vacuum in the can. This will result in a difference in drained weight because of the

TABLE 3

Effect of replacement of corn syrup for sucrose on drained weight of canned clingstone peaches [1,2]

% Replacement of sucrose by corn syrup solids in 40° Brix cover syrup	Corn syrup (64 Dextrose equivalent, acid-enzyme converted)			
	Net wt. oz.	Drained wt. oz.	% Retention	Equil. Brix at 20° C.
0	30.10 ±0.10	19.60 ±0.26	100.1	21.85 ±0.44
25	30.12 ±0	19.81 ±0.22	101.5	21.84 ±0.33
50	30.11 ±0.05	19.74 ±0.40	101.2	21.73 ±0.43
75	30.14 ±0.14	19.68 ±0.14	101.0	21.90 ±0.37
100	30.10 ±0.20	19.60 ±0.10	100.1	21.73 ±0.52

[1] Average of 12 cans for each sample, cut out at 6 months after canning.

[2] Clingstones canned at optimum maturity with a fill weight of exactly 19.5 oz. for each No. 2½ can.

variation in the ratio of syrup weight to fruit weight. To maintain a fairly narrow range for cut-out Brix and drained weight in the canned product, statistical quality control of these variables is necessary. The United States Standards for Grades of Canned Yellow Clingstone Peaches *(11)* states:

> "The container shall be filled with clingstone peaches as full as practicable, without impairment of quality. The product and packing medium shall occupy not less than 90% of the total volume capacity of the container."

The canner may vary the relative amounts of fruit and syrup as long as the minimum drained weight and the cut-out Brix can be met. In order to study a single specific factor, variations in other conditions must be kept at a minimum. The procedure used for canning in this work was to isolate one variable at a time, and all other factors were standardized. The results of this type of design are valuable in establishing basic information and trends that will serve as a valid basis for establishing quality control parameters useful in normal canning practices. Adjustment of fill weight and concentration of cover syrup are necessary to obtain a desired average equilibrium drained weight.

The drained weight of canned peaches was at a minimum in the "day-after" cut-out because of the difference in concentration gradient which caused movement of peach fluid to the syrup. When the sucrose concentration of the cover syrup is higher than

that of the fruit, peach fluid moves into the cover syrup rapidly, causing a lower drained weight after canning. On storage, diffusion of syrup into the peach tissue caused a gradual increase in drained weight with time. Changes in density, volume, and weight of both the cover syrup and peach take place till final equilibrium is reached. The rate, direction, and extent of diffusion of the solvent and solute molecules are governed by the laws of thermodynamics. The time required to reach equalization of all the constituents between the cover syrup and the peach tissue was controlled by the concentration gradient, mobility of the moving molecules, and resistance offered by the peach tissue. The peach tissue might be considered as an elastic material which may shrink or swell, depending on the concentration gradient between the cover syrup and the fruit. The canning process destroys the semi-permeable membrane of the peach cells and facilitates diffusion and exchange of the solvent and solute molecules between the cover syrup and the peach tissue. Peaches packed in plain water had a slightly higher drained weight than those packed in syrup. This is probably explained by the presence in the peach tissue of hydrophilic materials which encourage the penetration of water into the fruit. The weight of water penetrating into the fruit was more than the weight of soluble solids lost to the packing medium, resulting in a drained weight higher than the fill weight. The rate of translocation of soluble solids and fluids between the syrup and the fruit also varies depending on the type of fruit used.

The same explanation may apply to the effect of sucrose concentration in the cover syrup on the drained weight. High sugar concentration in the cover syrup creates a higher concentration gradient between the syrup and the fruit, thus causing more fruit fluid to pass into the syrup. During storage, soluble solids and syrup diffuse from the syrup into the fruit, causing the weight of the fruit to increase till equilibrium between the constituents is reached. The results obtained here seem to indicate that a Brix reading of 50° or 60° is necessary to produce a pronounced decrease in drained weight in the canned product. The concentration gradient between the cover syrup and the fruit is a decisive factor causing change in volume and weight of the syrup and the fruit. Recent work by Postlmayr, Luh, and Leonard *(8)* has shown the influence of processing time on texture and syrup viscosity of canned clingstone and freestone peaches. The syrup was more viscous in clingstone peaches heat-processed for a longer time. This was thought to be caused by the conversion of protopectin to water-soluble pectin during heating, thus resulting in a more viscous syrup. Water-soluble pectin can apparently diffuse from the space between the cell walls into the syrup. If the space originally occupied by the protopectin between the cell walls was penetrable by the higher molecular weight fraction of the corn syrup solids, the drained weight of the product canned in 64 dextrose-equivalent corn syrup should be comparable to that canned in plain sucrose syrup, provided the Brix readings of the cover syrups were the same. This has been found to be the case. According to Ross *(9)*, certain types of fruits have a slightly lower drained weight when packed in corn syrups with higher molecular weight fractions. This was probably caused by the difference in type of fruits and syrups used in his investigation.

The work of Adams and Hirst *(1, 4)* has indicated that the drained weight of canned strawberries, raspberries, blackberries, loganberries, and cherries was related to solubilization of pectin during processing. This was thought to be due to high temperature and acidity which caused hydrolysis and extraction of less readily soluble substances. Drained weights were lower in over-ripe and over-processed berries owing to breakdown of fruit structure and to osmotic action of the heavy syrup, causing shrinkage and shriveling due to loss of water by fruit to the syrup. Soft and ripe fruits interchange their constituents with the syrup more rapidly than firm, tough-skinned fruits. Clingstone peaches, with their firm texture, certainly belong to the latter type.

The work of Weast *(13)* is a new approach in forecasting the drained weight from the "day-after" cut-out data. Because of the linear relationship of storage time to drained weight on a semi-log scale, one may estimate the expected drained weight at any storage time from the reference point and the graph. However, the slope of the line may differ with different concentrations of sugar in the cover syrup. The work of Van Hook *(12)* has indicated that the diffusion coefficients of aqueous sucrose solutions diminish linearly from concentrations above one molar to at least the saturation concentration. If the same principle is applicable to the diffusion of soluble solids in canned clingstone peaches, the slope of the line for semi-log plot of time vs. drained weight may vary somewhat with the concentration of syrup used in canning. Assuming that the slope of the line is determined under specific packing conditions, this method would be useful in controlling production.

The minimum drained weight needed for clingstone peaches in heavy syrup for No. 2½ cans is 18.5 oz. The canners have to adjust the fill weight of the fruit as well as the concentration and quantity of cover syrup, depending on the cut-out Brix and drained weight desired for their product. Fruit size, which may influence the number of peach halves per can, must also be considered. In most instances, smaller fruits usually give a slightly higher drained weight than larger fruits, even if the conditions of canning are the same. This might be because a larger amount of syrup adheres between the fruits on the screen when the drained weight is determined. In this experiment, the effect of peach size was not investigated and fruits 2½ in. to 3 in. in diameter, typical of the peaches used for commercial canning in California (6 to 9 halves per No. 2½ can), were used throughout the investigation.

Fruits differ greatly in their reaction to canning. Cherries *(1, 2, 4, 9, 13, 15)* reach their minimum drained weight 3 days after canning. This indicates that the skin of the cherry fruit offers greater re-

sistance to movement of fruit fluid to the syrup. Thus, it is necessary to investigate each type of fruit for drained-weight studies.

In conclusion, the drained weight of canned clingstones varies greatly with storage time, cover-syrup concentration, and fill weight, but the effect of maturity is slight. Replacement of sucrose with corn syrup solids in the cover syrup does not cause any appreciable difference in drained weight. The effect of fruit size, seasonal variation, varietal characteristics, and horticultural procedures on the drained weight of the canned product remains to be investigated. From what we have learned about the effect of maturity, we may assume that the influence of these variables on drained weight will be small.

SUMMARY

Factors influencing drained weight and Brix readings of canned, halved clingstone peaches were investigated. These include storage time, concentration of cover syrup, fill weight, maturity, and the use of corn syrup in place of sucrose. Immediately after canning, the drained weight fell below the fill weight because peach fluid was lost to the cover syrup. Drained weight increased rapidly during the first week after canning and then slowly until a maximum value was reached in 90 days as a result of penetration of syrup into the fruit. Right after canning, the drained weight was only 89% of the fruit fill weight. The weight retention after 30 and 90 days' storage was 99.0% and 101.5% of the fruit fill weight, respectively. Concentration of sucrose in the cover syrup was found to have a pronounced effect on the equilibrium drained weight of the canned product. Samples canned in sucrose syrups of 40° Brix or lower yielded drained weight higher than the fill weight. Those canned in 50° Brix or higher yielded drained weight lower than the fill weight. For peaches canned in water for dietetic purposes, a weight retention of 103.7% was obtained at equilibrium. The influence of maturity on drained weight is small as compared with other factors. Replacing sucrose with 64 dextrose-equivalent corn syrup in the cover syrup caused no significant difference in drained weight of the canned product at equilibrium.

The importance of syrup concentration, fill weight, and storage time to drained weight and Brix readings is discussed.

Acknowledgment

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Shrinkage and Organoleptic Characteristics of Beef Aged in Controlled Environments[a,b,c]

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SINCE THE CONSUMER demands tenderness as well as other palatability factors in meat, improvement in the quality of beef through aging is a long-established practice in the meat industry. However, the problem of aging and tenderizing meat properly and economically with the least possible amount of wastage due to shrinkage and cutting loss is of paramount importance to the meat packer. If he is to age meat correctly, it is necessary that the product be held at definite temperatures to permit the enzymes in the meat to carry on their normal functions of breaking down the proteins in the muscles. Many workers such as Bate-Smith *(1)* believe that the enzymes, presumably proteases, are responsible for the alterations in tenderness. In addition, proper humidity in the aging room must be maintained in order to minimize shrinkage of the product and discoloration of the external fat during high temperature aging.

It has been known for many years that the aging process could be accelerated by elevating the temperature in order to promote additional enzymatic activity. Euell *(4)* has shown that the speed of tenderization doubles for each 18° F. rise in temperature. In order to control microbial growth on the surface of beef during rapid aging, industry as well as many other investigators such as Reutschler and Nagy *(9)*, McCarthy and King *(7)* and Sleeth *et al. (10)*, have found the use of germicidal lamps extremely beneficial.

The work reported here follows directly from an earlier paper from this laboratory. In this previous report, shrinkage, cooking loss, organoleptic, and shear values were determined for round, rib, and T-bone steaks from quarters and wholesale cuts of Choice and Good grades of beef aged under different environmental conditions. This report is a continuation of the above with particular emphasis on shrinkage and palatability characteristics of beef of different weights and grades. Graphs are presented showing shrinkage and organoleptic characteristics of beef aged under these controlled environmental conditions. The authors feel that such information will serve a twofold purpose: (a) supply information to the meat packer or processor as to the approximate results he can expect from different aging procedures and (b) record data concerning the efficiency of aging beef at elevated temperature as compared to standard aging room temperatures (35–36° F.).

Studies previously reported at this station show that beef aged at a higher temperature (68° F.) is more tender, has more flavor, and has more desirable cutting characteristics than beef aged at 34° F. for a comparable period. In addition, the work indicates that environmental conditions affect moisture losses during processing.

This study is concerned with a further investigation of (1) weight losses due to shrinkage as influenced by (a) length of aging, (b) quality of product, (c) temperature, (d) humidity, (e) air velocity, and (f) ultraviolet radiation, and (2) organoleptic characteristics of steaks stored at 0° F. for 0 months. Adjacent steaks were removed and stored for periods of 2, 4, 8, and 12 months. The effect of these different storage periods on steaks aged under various environmental conditions will be reported in a later paper.

EXPERIMENTAL PROCEDURE

The procedure for the different experiments conducted for this report is described as follows: each experiment refers to a figure which is contained in the paper; i.e. Figure 1 refers to Experiment 1, Figure 2 refers to Experiment 2, etc.

Each test consisted of the following number of cattle: Experiment 1, 7; Experiment 2, 16; Experiment 3, 4; Experiment 4, 4; Experiment 5, 8; Experiment 6, 7. The cattle, weighing 800–850 pounds in all of the tests, were slaughtered at the Missouri Station Laboratory. Hot carcass weights were recorded at the time of slaughter. Carcasses were then placed in a chill room at 36° F. and chilled 24 hours to an internal temperature of 45° F. However, carcasses from cattle reported in Figures 5 and 6 were only chilled to an internal temperature of 65° F.

After the initial chilling period, the carcasses were weighed, quartered and/or cut into wholesale cuts, and then reweighed. Weight losses were recorded daily throughout the aging periods to determine shrinkage losses.

Aging, sampling, organoleptic, and Warner-Bratzler Shear procedures are given in an earlier report of this study *(10)*. The aging room conditions for each test are described in footnotes at the bottom of each figure.

Temperature of the aging room was maintained by an electric heater. A small jet of live steam was induced into the aging room to keep the relative humidity constant.

Rib steaks from the forequarter and T-bone and top round steaks from the hindquarter were used for organoleptic evaluations.

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[b] Journal Series Paper No. 1752, approved by the Director of the Missouri Agricultural Experiment Station.

[c] Financed in part by a grant from Pasteuray Corporation, St. Louis, Missouri.

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An analysis of variance of the taste panel data for each palatability factor was used to determine significance between treatments and animals.

RESULTS AND DISCUSSION

Figures 1 through 6 indicate the per cent shrinkage, and the mean value scores for tenderness, flavor, aroma, juiciness and flavor of fat. Each organoleptic value represents the average scores of six judges.

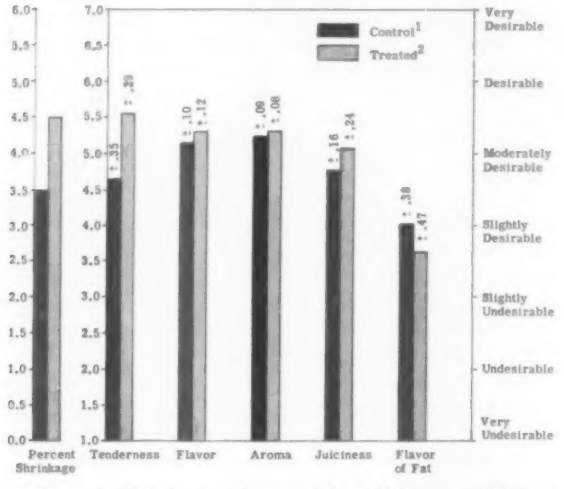

Figure 1. Effect of environmental conditions on shrinkage and palatability characteristics of U. S. good beef ribs.

[1] Control: Aged 6 days at 36° F., 80% R.H., air flow 20–25 L.F.M.

[2] Treated: Aged 6 days at 57° F., 80% R.H., air flow 20–25 L.F.M., 200 microwatts of ultraviolet radiation per sq. cm. at the surface of the product.

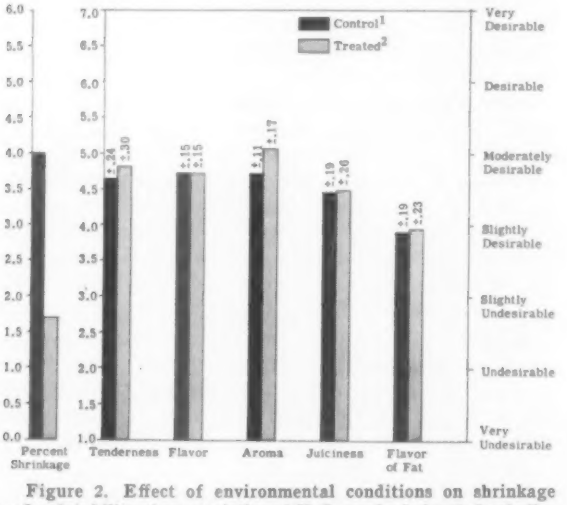

Figure 2. Effect of environmental conditions on shrinkage and palatability characteristics of U. S. good wholesale beef ribs.

[1] Control: Aged 12 days at 34° F., 90% R.H., air flow 15 to 20 L.F.M.

[2] Treated: Aged 2 days at 68° F., 90% R.H., air flow 15 to 20 L.F.M., 150 microwatts of ultraviolet radiation per sq. cm. at the surface of the product.

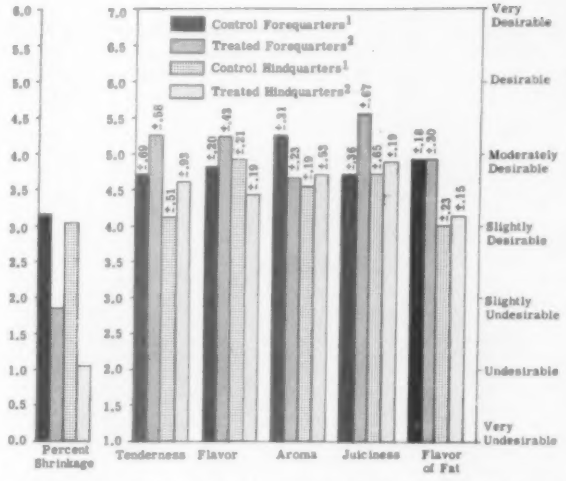

Figure 3. Effect of environmental conditions on shrinkage and palatability characteristics of U. S. choice beef quarters.

[1] Control: Aged 14 days at 40° F., 80% R.H., air flow 15 to 20 L.F.M.

[2] Treated: Aged 5 days at 68° F., 80% R.H., air flow 15 to 20 L.F.M., 150 microwatts of ultraviolet radiation per sq. cm. at the surface of the product.

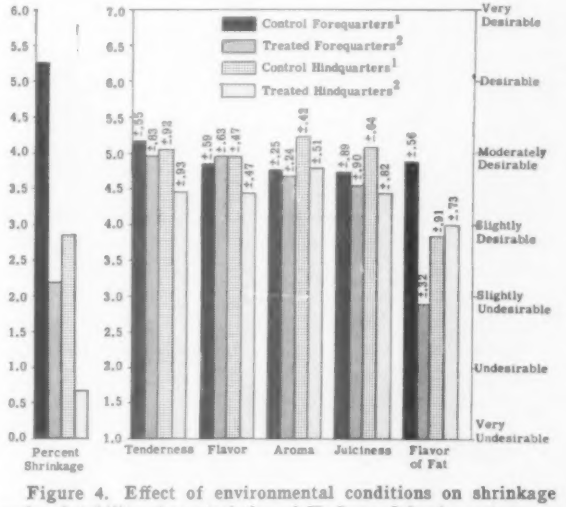

Figure 4. Effect of environmental conditions on shrinkage and palatability characteristics of U. S. good beef quarters.

[1] Control: Aged 14 days at 40° F., 80% R.H., air flow 15 to 20 L.F.M.

[2] Treated: Aged 3 days at 68° F., 80% R.H., air flow 15 to 20 L.F.M., 150 microwatts of ultraviolet radiation per sq. cm. at the surface of the product.

Shrinkage. From the physical standpoint, the overall shrinkage picture appears to be based on the relative humidity, air flow, and temperature of the aging room, the grade of cattle, and the length of the aging period. However, the majority of the moisture loss does not occur during the first 2 or 3 days as has often been suspected. In an earlier report *(10)*, it was shown that a consistent line relationship is formulated for shrinkage; i.e. a consistent amount of shrinkage for each day of aging. The data in Figures

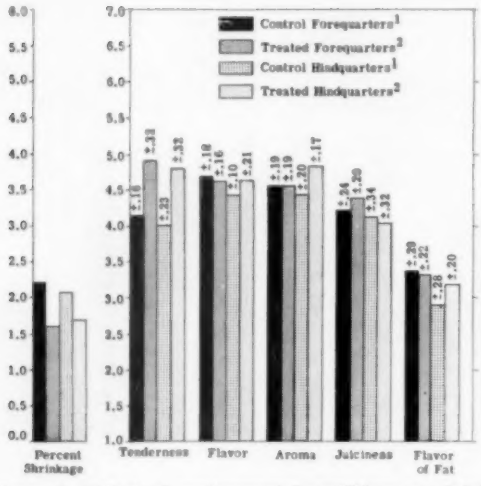

Figure 5. Effect of environmental conditions on shrinkage and palatability characteristics of U. S. good beef quarters.

[1] **Control: Aged 3 days at 36° F., 90% R.H., air flow 25–30 L.F.M.**

[2] **Treated: Aged 3 days at 76° F., 90% R.H., air flow 25–30 L.F.M., 125 microwatts of ultraviolet radiation per sq. cm. at the surface of the product.**

1–6 indicate that on the basis of days aged the average per cent shrinkage per day for Choice and Good quarters and wholesale cuts aged in an 80% relative humidity was 0.52% for the controls and 0.54% for the treated. At 90% relative humidity, the shrink for the control and treated quarters and wholesale cuts was 0.32 and 0.46% per day, respectively. Consequently, under the controlled environmental conditions employed in conjunction with a higher relative humidity in the aging room, the moisture loss was substantially reduced.

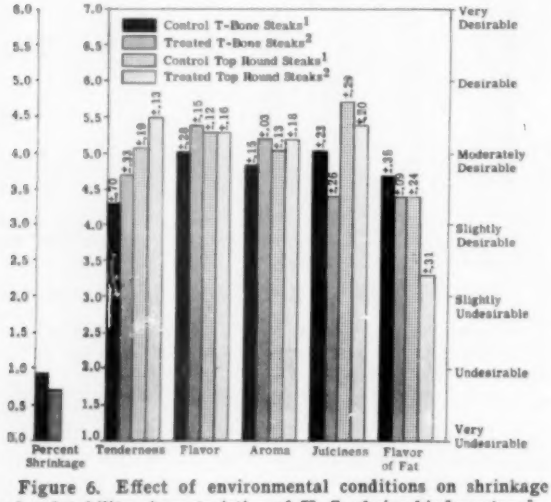

Figure 6. Effect of environmental conditions on shrinkage and palatability characteristics of U. S. choice hindquarters.[3]

[1] **Control: Aged 3 days at 36° F., 90% R.H., air flow 15–20 L.F.M.**

[2] **Treated: Aged 3 days at 86° F., 75% R.H., air flow 15–20 L.F.M., 125 microwatts of ultraviolet radiation per sq. cm. at the surface of the product.**

[3] **T-bone and top round steaks were used to evaluate the palatability factors.**

With respect to grade, Figures 3 and 4 demonstrate that Choice fore- and hindquarters shrank less than those of comparable weight in the Good grade. These were aged under the same relative humidity. This reveals the influence the external fat covering has on moisture losses and should be considered by the meat packer or processor when aging meat.

Figure 6 discloses the small amount of shrinkage of Choice hindquarters aged at 86° F. and 90% relative humidity. The average moisture loss per day for the controls is 0.30% while the treated lost 0.20% per day. Experiments not reported in this paper have shown the shrinkage from Choice hindquarters aged two days at 100° F. and 100% relative humidity was practically negligible.

An additional influence of high relative humidity in the high temperature aging room with ultraviolet radiation is the preservation of the normal white color of the subcutaneous fat. Under humidity conditions as low as 80%, fat has a tendency to become slightly yellow. However, this condition was eliminated by aging at 90 to 100% relative humidity.

Tenderness. In Figure 1, difference in tenderness approached significance for the treated ribs. This indicates that in a comparable aging period of 6 days the tenderness of ribs aged at 57° F. increased over those held at 36° F. The results in Figures 2, 3 and 4 confirm our previous observations *(10)*, and other investigators *(3)*, that tenderness values for beef quarters and ribs aged 2, 3, and 5 days at 68° F. were found to be comparable to those aged 12 and 14 days at 34° F. and 40° F. respectively. A statistical treatment of the data showed no significant tenderness differences between treatments. This is important to the processor as it will permit him to keep his inventory low. He will also have a greater turnover of product in a shorter period of time with a saving in refrigeration costs.

Mean panel scores for T-bone and top round steaks from Choice hindquarters aged at 36° F. (control) and 86° F. (treated) are shown in Figure 6. The scores show that the control and treated top round steaks were more tender than the control and treated T-bone steaks. This is contrary to the commonly held belief. However, it does lead us to postulate that top round steaks may be very acceptable to the consumer if aged under the proper conditions.

Evaluation of the tenderness values show no apparent differences between the Choice and Good grade in this test. These results are in agreement with two earlier reports by Wierbicki *et al. (11, 12)* that intramuscular fat does not affect tenderness but appears to be a sex characteristic.

Flavor. In all experiments (Figures 1 through 6), there were slight but not significant differences in flavor due to treatment. Mean panel scores from high temperature-short time aged ribs and quarters were comparable in flavor to those aged at a low temperature and a long holding period.

There was no difference in flavor as shown by the palatability committee between the Choice and Good grades of ribs and quarters. This is in agreement with Black *et al. (2)* and Hedrick *(5)* who found that fatness of the animal did not have any significant influences on the flavor of cooked samples However, the results of this study do not support the work of Marion *et al. (6)* who found that carcasses from the higher grades of beef gave slight indications of more desirable flavor in the lean meat.

Aroma. Although not significant, there was considerable variation in aroma as shown by the palatability committee scores between the control and treated. The difference was in favor of the treated samples in Figures 1, 2, 3, (hind quarters), 5, and 6. This was possibly due to the effect of the higher temperature in developing certain flavor constituents. The control forequarters in Figure 3 and controls (fore- and hindquarters) in Figure 4 were slightly higher in mean palatability score values. Again, the differences were not significant.

Grade did not have any significant influence on aroma. This is in agreement with Marion *et al. (6)* who found no apparent difference in aroma of meat from Choice grade animals as compared to those of lower grades.

Juiciness. Juiciness scores remained essentially the same for the controls and treated product in all experiments. Again, difference between grades did not show any appreciable influence in the panel scores.

Flavor of fat. The controls in Figure 1 show a significant difference (.05 level). This difference was due to an excess of ozone and germicidal radiation on the treated product. However, in the latter experiments, the difference between control and treated product was not significant. This was brought about by lowering the concentration of ultraviolet radiation (2537 Å) from 200 to 125 microwatts per square centimeter at the surface of the product. (Radiation was measured with a Germicidal Ultraviolet Intensity Meter manufactured by the General Electric Company). Further, it was shown in tests (not reported here) that by limiting the time of ultraviolet radiation by intermittent exposures of 12-hour intervals during the duration of the tests, comparable results were obtained. This procedure provides satisfactory product protection as well as eliminates additional trimming loss and rancidity development due to excessive radiation.

Thawing and cooking losses. Tables 1 and 2 give mean and "F" values for thawing (drip) and cooking loss. As was previously reported, the results of all tests, except the hindquarters in Figure 5, indicate that the treated product lost more moisture due to thawing and cooking than the controls. However, this difference was not significant except for the thawing loss of rib steaks in Figure 5. This was highly significant (.01 level). These results are in agreement with previous observations by Wierbicki *(12, 13)* that aged meats release less moisture during thawing and cooking than the non-aged.

TABLE 1

Mean and F-values for thawing (drip) loss for round, rib, and T-bone steaks for experiments 1–6

	Mean value[1]				F-value	
	Treated[2]	S.E.	Control[3]	S.E.	Treatment	Animal
Fig. 1 (Rib)	1.76	±.41	1.74	±.40	.01	7.02*
Fig. 2 (Rib)	.81	±.12	.91	±.09	.30	.31
Fig. 3 (Rib)	1.75	±.36	.93	±.21	17.14**	7.81*
3 (Round)	2.69	±.69	2.35	±.63	.48	6.04*
Fig. 4 (Rib)	1.88	±.77	1.31	±.16	3.16	.62
4 (Round)	1.60	±.49	1.64	±.85	.01	10.78*
Fig. 5 (Rib)	1.86	±.21	.82	±.20	17.83**	21.82**
5 (Round)	3.27	±.40	3.56	±.48	1.29	11.00*
Fig. 6 (T-Bone)	.50	±.14	.45	±.17	.05	1.61
6 (Round)	2.16	±.81	2.52	±.91	3.00	5.07

[1] Based on percentage thawing loss.
[2] Refer to experimental conditions at the bottom of each figure.
[3] Refer to experimental conditions at the bottom of each figure.
* Significant at .05 level.
** Significant at .01 level.

INTERNAL TEMPERATURE OF HINDQUARTERS DURING AGING

Since the elevated temperature has such an important role in tenderization, the relative internal temperature of the product at any given time during the aging period is essential. Figure 7 shows the increase of the internal temperature of a hindquarter previously chilled to 57° F. and then held for a period of 68 hours at 93.5° F. and also the internal temperature of a hindquarter placed directly into the aging room from the slaughter floor and held for a similar time and temperature. At the end of these periods, the products were placed into a 40° F. chill room for 28 hours.

The internal temperature of the chilled hindquarter increased rapidly but leveled off at the end of 32 hours. Twelve additional hours were required fo this temperature to reach the aging room temperature where it leveled off during the remaining aging period.

In 14 hours, the internal temperature of the hindquarter, placed directly from the slaughter floor into aging, reached 89° F. The temperature increased gradually over a 20-hour period until it leveled off at 93.5° F. The phenomenon of the internal temperature falling below the aging room temperature cannot be satisfactorily explained at this time.

After the quarters were placed in the chill room the

TABLE 2

Mean and F-values for cooking loss for round, rib and T-bone steaks for experiments 1–6

	Mean value[1]				F-value	
	Treated[2]	S.E.	Control[3]	S.E.	Treatment	Animal
Fig. 1 (Rib)	24.42	±1.54	25.13	±1.61	.47	8.14*
Fig. 2 (Rib)	25.04	±1.03	24.84	± .98	.17	.74
Fig. 3 (Rib)	24.65	± .90	25.18	±1.04	.23	2.05
3 (Round)	29.25	±1.31	30.06	±2.21	.41	7.25*
Fig. 4 (Rib)	27.23	±1.86	25.04	±1.23	9.56*	8.86**
4 (Round)	33.63	±2.41	32.47	±2.70	.08	1.25
Fig. 5 (Rib)	32.96	±2.59	31.09	±1.89	1.84	9.88*
5 (Round)	32.34	±1.21	33.83	±1.48	1.43	3.75
Fig. 6 (Rib)	26.98	±1.53	25.09	±1.06	.96	.88
6 (Round)	22.24	±1.17	22.41	±1.63	.01	.89

[1] Based on percentage cooking loss.
[2] Refer to experimental conditions at the bottom of each figure.
[3] Refer to experimental conditions at the bottom of each figure.
* Significant at .05 level.
** Significant at .01 level.

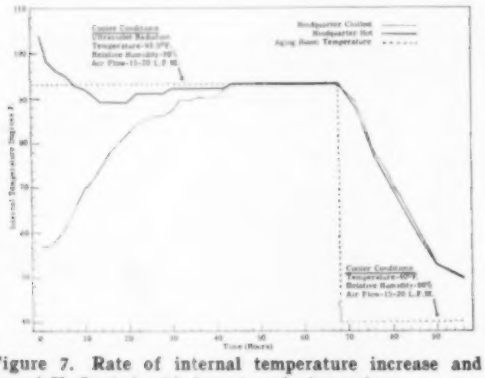

Figure 7. Rate of internal temperature increase and decrease of U. S. choice hindquarters during aging.

decrease in the internal temperature was rapid, requiring only 28 hours to reach 50° F.

SUMMARY

Choice and Good hindquarters, forequarters and wholesale ribs from 46 cattle weighing 800–850 pounds were aged at temperatures of 36° F., 40° F., 57° F., 68° F., 76° F., and 86° F. This product was aged under relative humidities varying from 80 to 90% and air velocities of 15 to 20 lineal feet per minute. To control microbial growth at the elevated temperatures, ultraviolet radiation was used.

On the basis of the results, the following findings appear most significant.

Grade, length of the aging period, and relative humidity of the aging room affect shrinkage. Tenderness, flavor, aroma, and juiciness values for beef quarters and ribs aged 2–3 days duration at the higher temperatures are comparable to those aged 12–14 days at the normal aging temperatures.

Acknowledgments

The authors wish to express their appreciation to Mr. Lyle D. Spence for his invaluable assistance in the collection and analysis of the data. The assistance of the six-member taste panel for their organoleptic evaluations of samples of all tests during this investigation is also acknowledged.

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The Cooking Properties of Some New Durum Wheat Varieties*

(Manuscript received July 5, 1957)

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HARRIS AND KNOWLES *(4, 5)* have described the methods of assessing the cooking quality of macaroni, originally developed by Barasio *(3)*, and modified by Binnington, Johannson, and Geddes *(2)*. Briefly the procedures consist of determining the water absorption (measured by gain in weight) and degree of disintegration and tenderness of the macaroni after cooking under specified, uniform conditions. It has been shown that the weight of the cooked macaroni is a reliable index of the water absorption *(2)*, and that it is not necessary to measure the volume of the raw and cooked macaroni which are rather tedious procedures.

This report adds information to that already available on the cooking and quality properties of macaroni and the relations among them. Relative effects of wheat variety, station, and year of growth on cooking quality are also analyzed. As far as the authors are aware, a study of this nature has not been previously published.

Figure 1. A section of the macaroni laboratory, showing the "Magni Whirl" cooking bath.

EXPERIMENTAL

Materials and methods. Durum wheats included in this investigation were new hybrids possessing resistance to the 15-B stem rust complex and standard varieties such as Mindum, which was released for farm growth before 15-B became a major threat to North Dakota durum production and later Sentry. These standard varieties are satisfactory for milling and macaroni processing when not attacked by 15-B. Four new varieties carrying rust resistance and satisfactory quality have been released by the North Dakota Station. A description of these with a summary of their milling and macaroni processing properties was published in the North Dakota Station Bimonthly *Bulletin (8)*. The names of the 4 wheats with their former nursery numbers are: Langdon (LD 372), Ramsey (LD 369), Towner (LD 370), and Yuma (LD 364). The LD refers to "Langdon Durum". The wheats were grown and tested for 3 years at 5 stations throughout the principal durum area in North Dakota.

Table 1 shows the comparative milling and macaroni processing data from these varieties. Towner was the lowest in color score, but was still acceptable. Yuma tended to have a reddish tinge in the macaroni which some manufacturers have deemed undesirable. This variety had the highest absorption, and differed from the others in mixing requirements and physical dough properties because of a strong, non-elastic gluten. Sentry, on the other hand, produced a softer, more extensible dough than the average.

The cooking procedure was as follows—25 g. of dried macaroni, broken into 7 cm. lengths, were placed in lipless, tall form 500 ml. beakers containing 250 ml. of distilled water and then transferred to the bath at 101° C. (Fig. 1). They were cooked for 30 minutes, being stirred gently twice to prevent the strands from sticking together. At the end of the period the cooked macaroni was drained in a Buchner funnel without suction for 10 minutes, during which the macaroni was washed with boiling distilled water. Drainings and washings were collected in tared 250 ml. beakers, then evaporated to dryness at 100° C. and the weight of residue determined. The drained cooked macaroni was weighed and reported as cooked weight. Five representative strands of the cooked material were taken for the tenderness test, yielding 5 replications for each sample. This test and the technique involved have been described in detail by Binnington, Johannson and Geddes *(2)* and Harris and Knowles *(6)*. Essentially this test measures the pressure needed to collapse the tube of cooked macaroni, the pressure being supplied by addition of mercury to a flask connected to a disk which in turn exerts pressure on the strand of macaroni until it collapses. A tenderness score is then calculated from a curve traced by the tenderness tester resembling, in a modified form, the one described by Binnington *et al.* Analytical procedures for determining protein, moisture, and ash content etc. are described in Cereal Laboratory Methods *(1)*.

RESULTS AND DISCUSSION

Means and variability. The mean results and variability obtained from cooking 126 samples are shown in Table 2. Semolina protein and ash content are also included. For direct comparisons with values for cooked weight and residue previously published *(2, 6)* it is necessary to multiply the present results by four since these represent 25 g. of material while the former data were on the basis of 100 g. On this basis the values in Table 2 become 348.0 and 4.2 g., respectively. Harris and Knowles *(6)* reported 328.6 and 3.5 g. for corresponding experimental milled semolina and 331.2 and 4.5 g. on macaroni *(2)* made from a series of 10 commercial flours and semolinas *(4)*. These all appear to be of the same general order of magnitude. The present tenderness scores are all sub-

*Contribution from the Department of Cereal Technology. Published with the approval of the Director of the North Dakota Agricultural Experiment Station.

TABLE 1

Variety means for milling and processing quality arranged in order of decreasing macaroni color score

	Semolina protein content[1]	Semolina yield[1]		Semolina ash content[1]	Specks 10 sq. in.	Absorption[1]	Visual color score of macaroni	Mixing pattern[2]
		Unpurified	Purified					
	%	%	%	%		%		
Langdon	13.2	72.8	58.6	0.61	25	27.8	9.0	Weak 5.3
Sentry	13.9	71.8	57.6	0.61	43	28.0	9.0	V. Weak 2.0
Mindum	12.3	70.4	56.7	0.60	17	28.2	8.5	Medium 5.3
Ramsey	13.2	72.5	58.1	0.64	27	28.0	8.2	Weak 3.5
Yuma	13.9	72.0	57.4	0.61	13	29.0	8.2	Strong 6.8
Towner	13.1	70.9	55.6	0.59	24	28.2	7.2	Weak 3.4
Average value	13.3	71.7	57.3	0.61	25	28.2	8.4	M. Weak 4.0

[1] Expressed on 13.5% moisture basis.
[2] V = very, M = medium.

stantially higher, and would fall into the "very tough" classification (over 160) of Binnington *et al.* The variability for cooked weight reported by Harris and Knowles was somewhat greater than shown in Table 2.

As might be expected the mixing score was the most variable, showing the effect of variety. It has been repeatedly found in this Laboratory that wheat varieties vary widely in mixing requirements, and that this property must be considered when appraising either new hard red spring or durum wheats for commercial acceptance. The second largest variability was in the tenderness score.

Table 3 provides information on the relations between the different properties of semolina and macaroni. The most important relations were those between weight of mercury and tenderness score, which

TABLE 2

Means and variability of the measurements (N = 126)

Variable	Mean	Standard deviation	Coefficient of variation
			%
Semolina protein content	13.0%	1.26%	9.7
Cooked weight	87.0 g.	3.87 g.	4.8
Residue	1.05 g	0.154 g.	14.7
Weight of mercury	1423.97 g.	291.46 g.	20.5
Tenderness score	164.52	29.75	18.1
Mixing score	4.14	1.63	39.2
Semolina ash content	0.60%	0.076%	12.6

was expected, and semolina protein content and tenderness score. Thus higher protein content tends to produce tougher cooked macaroni. However, Harris and Knowles *(6)* found no significant correlation between these variables for 32 samples grown at Fargo, and Langdon, 12 of which had been damaged by blight and associated diseases in 1940. Earlier work published by these workers showed a positive correlation of 0.731 between these variables. It is probable that the correlations vary from year to year with the properties of the wheats and the effect of weather conditions during seasonal growth. The number of samples included in the present report are much larger and cover a wider range of yearly and local environments than previous reports from this Station and should furnish reliable data on these relationships.

Varietal and environmental effects. Table 4 shows the means of the varieties for the 3 chief factors of

TABLE 3

Correlation coefficients between the cooking and other data (N = 126)

Variables correlated	Coefficient
Cooked weight and residue	+0.192*
Weight of mercury and tenderness score	+0.843**
Cooked weight and tenderness score	−0.153
Cooked weight and weight of mercury	−0.226**
Tenderness score and mixing score	+0.178*
Semolina protein content and cooked weight	−0.142
Semolina protein content and tenderness score	+0.622**
Semolina protein content and residue	+0.033
Semolina protein content and mixing score	+0.023

* Indicates that the 5% level of significance was attained.
** Indicates that the 1% level of significance was attained.

cooking quality. For cooked weight Sentry was highest although differences between varieties were not great. Sentry was also highest in residue. Yuma was lowest for both these factors, but yielded the highest tenderness score and would be denoted as producing the "toughest" macaroni of the 6 wheats. Mindum produced the tenderest cooked macaroni but it would still be ranked as "tough" in Binnington's classification. Of course these are arbitrary values so far as actual tenderness is concerned and may not represent the opinions of a panel of judges. They do show, however, that marked differences exist between samples of cooked macaroni from different durum varieties, and varieties which diverge greatly from the average of accepted durums may well be viewed with suspicion for their macaroni acceptability to the consumer.

Table 5 is an analysis of variance of the semolina protein content and cooking quality data. In this analysis the main sources of variation are sorted out and the relative effect of each evaluated. The significance of the differential reactions of each of the sources of variation with each other source, or the interactions, are also tested for statistical significance *(8)*.

TABLE 4

Mean cooking quality data
Arranged in order of decreasing macaroni color score

	Cooked weight[1]	Residue[1]	Tenderness score
	g.	g.	
Mindum	88.02	1.08	149.83
Sentry	90.25	1.11	172.37
Ramsey	88.66	1.05	152.45
Towner	84.77	1.05	150.44
Langdon	84.98	1.08	158.30
Yuma	83.40	1.02	191.17

[1] Expressed on 13.5% moisture basis.

TABLE 5

Analysis of variance of the data

Source of variation	Degrees of freedom	Semolina protein content		Cooked weight		Residue		Tenderness score	
		Sums of squares	Variance	Sums of squares	Variance	Sums of squares	Variance	Sums of squares	Variance
Between varieties	5	18.92	3.784**	402.22	80.444**	0.0693	.0139	13439.69	2687.94**
Between stations	4	52.06	13.015**	88.62	22.155	0.2644	.0661**	17366.95	4341.74**
Between years	1	5.05	5.050**	1.26	1.260	0.3697	.3697**	11239.49	11239.49**
Interactions									
Varieties × stations	20	5.44	0.272	138.48	6.924	0.1501	.0075	7372.22	368.61
Varieties × years	5	1.56	0.312	56.62	11.324	0.0407	.0081	89.14	17.83
Stations × years	4	3.72	0.930**	72.94	18.235	0.3487	.0872**	6245.77	1561.44**
Varieties × stations × years	20	4.06	0.203	166.15	8.308	0.1462	.0073	4659.78	232.99
Total	59	90.81		926.29		1.3891		60413.04	

** Indicates that the 1% level of significance as attained.

For semolina protein all three of the main sources of variation had very significant effects with the stations exerting the largest influence. As shown in the comparative estimate of the importance of these sources from which bias has been removed [Rosander *(7)*], the effect of the stations was approximately three times that of the varieties and almost seven times that of years (Table 6). The only significant

TABLE 6

Unbiased estimates of variance

Source of variation	Degrees of freedom	Variance	Estimated variance	Per cent of total variance
Semolina protein content				
Between varieties	5	3.784	0.348	18.67
Between stations	4	13.015	1.059	56.81
Between years	1	5.050	0.155	8.31
Interactions	49	0.302	0.302	16.21
Total	59		1.864	100.00
Tenderness score				
Between varieties	5	2687.94	231.311	17.81
Between stations	4	4341.74	330.575	25.45
Between years	1	11239.49	362.155	27.88
Interactions	49	374.83	374.835	28.86
Total	59		1298.876	100.00

interaction was between stations and years. In other words there was a differential response among the stations to the year in which the wheat was grown. For cooked weight the results were quite different, with only varieties significantly influencing the variance. Thus a variety could be grown at any of the locations without appreciably affecting the cooked weight. Since the interaction variance was greater than that of two of the main causes of variation, no correction for bias is needed. The analysis shows the opposite effect for residue as compared to cooked weight, as variety was the only main source of variation without significant effect. From this it seems that any approved durum wheat would be satisfactory as far as macaroni disintegration during cooking is concerned. As for semolina protein there was a significant interaction between stations and years. Again no correction for bias was required.

Tenderness score was very significantly affected by all the main causes of variation, with varieties having the least influence. The relative effects of stations, years, and the interactions were much the same (Table 6). As for semolina protein content and residue there was no environmental effect on cooked weight, which appears to be primarily a varietal characteristic.

SUMMARY AND CONCLUSIONS

Macaroni made from 126 samples of durum wheat grown in experimental plots at North Dakota stations in 1954, 1955 and 1956 was evaluated for cooking quality. The principal quality properties measured were cooked weight, degree of disintegration and tenderness score. From this investigation it seems that macaroni toughness, as indicated by tenderness score, increases with protein content.

There were very marked differences between durum wheat varieties in dough mixing requirements. Variations in tenderness score were also marked but smaller than for mixing requirements.

As expected semolina protein content was very significantly affected by wheat variety, location of growth, and year of growth. Of these, location of growth had the most pronounced effect, and year of growth the least.

For cooked weight, variety alone exerted a significant influence, while for residue variety was without effect, years having the largest influence. For tenderness score location and year of growth had approximately equal effects, while variety was less influential.

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Causes of Scald in Red Tart Cherries [a,b]

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(Manuscript received May 14, 1957)

CHERRY PROCESSORS, particularly in New York State, have in recent years been considerably troubled with cherry scald. This is a post-harvest condition which develops in the red tart cherry during the course of handling and conditioning the fruit prior to pitting and packing. It has been variously called "lug scald" or "tank scald" by processors and growers depending on where it occurs. However, our experience has shown that these two forms differ only in extent of affected tissue.

On the other hand, it is important for purposes of discussion to differentiate between scald and the oxidative browning which often accompanies it. We may define scald as a loss of red pigment from the skin of the cherry. This occurs in small circular, sometimes depressed areas as in "lug scald" or in irregular blotches which may involve most of the cherry surface as in "tank scald" (Figure 1). These scalded areas are light pink. Although it is believed that some of the red pigment is actually destroyed, much of it merely migrates into the yellow flesh under the skin or into the soak water.

These same areas of skin may subsequently turn brown along with the tissue beneath, affecting flavor as well as color and appearance. This is believed to be an enzymatic oxidation which normally follows destruction of cellular tissue *(1)*. Since oxidation invariably accompanies severe scald in red cherries, it is commonly regarded as part of this injurious change. For practical purposes this is defensible, since oxidation does the greater part of the damage to the processed product. However, the two processes are not interdependent, but merely stem from the same causes. Although we shall define scald here only as the loss of pigment from the skin, it must be remembered that a brown discoloration will accompany severe cases.

Cherry scald became a major problem to processors about 10 years ago. This coincided somewhat with several major changes in the processing scene, including the increased importance of the frozen pack, the rapid increase in the size of the industry, and the consequent use of migrant, rather than domestic, labor for picking. It appears that this increase in the scale of operation resulted in less careful handling of the fruit. The consequent loss of quality has been especially evident in the frozen product, which is more sensitive to this type of damage.

The importance of these changes had not been widely appreciated. The increase in scald was variously attributed to the use of new spray materials, the increase in nitrogen fertilization, and too much or too little rain. Apparent seasonal variation in the seriousness of the scald seemed to rule out cultural practices in favor of seasonal variables. Consistent seasonal effects, however, could not be detected. If there was widespread awareness of the effect of rough handling on the incidence of scald in 1952 when the present research was initiated, it was not apparent to the investigators.

Some preliminary tests designed to demonstrate the nature of scald soon showed that a number of processing variables are involved. These are: the degree of bruising, the time elapsed between picking (bruising) and packing, and the temperature to which the fruit was subjected during this post-harvest interval. It also appeared to make a difference whether the surface of the cherries was wet or dry. It was observed that bruised cherries when held in warm 90° F. air would scald only where wet, e. g., at the point of contact with the supporting surface. When cherries were held in warm water, the scald appeared in irregular blotches wherever the cherry was bruised. But cherries carefully bruised so as to remain dry on the surface, scalded at scarcely perceptible rates even when subjected to 95° F. for 12 hours. Oxidative changes in skin and flesh, visible as a darkening of the skin and browning of the bruised flesh, occurred independently

[a] Presented at the Pittsburgh Meeting of the Institute of Food Technologists, May 14, 1957.

[b] Journal Paper No. 1087, dated July 15, 1957, New York State Agricultural Experiment Station, Cornell University, Geneva, New York.

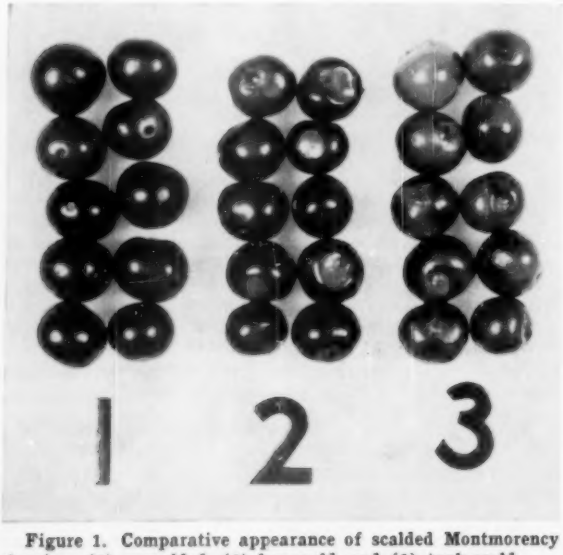

Figure 1. Comparative appearance of scalded Montmorency cherries: (1) unscalded, (2) lug scald, and (3) tank scald.

under the latter conditions. Little scald was observed to form at low temperatures, such as 50° F., or during short intervals of time such as an hour or two.

From these preliminaries it was decided to investigate the effects of bruising, time, and temperature throughout the ranges in which they generally occur. Since in commercial practice the cherries are always wet with juice or soak water, the wet-surface variable was not studied further.

Thompson and Spangler *(6)* observed that some defects, such as badly scalded cherries, scored in the raw product rarely became sufficiently defective to be scored as defects in the processed product unless the flesh was badly discolored. Badly scalded fruit, however, affected the general color of the frozen product. Marshall, Robertson, Bedford and Case *(5)* found that prolonged soaking increased culls which must be removed before processing but did not identify these culls as scalded or oxidized cherries. Marshall *(4)* does not mention cherry scald in his monograph on cherries. Whittenberger, Hills, Robertson and Case *(9)* found that bruising had little effect on the color of the final product under the experimental conditions which they employed. Levin and Gaston *(3)* observed that transporting cherries from orchard to processing plant in truck-mounted tanks reduced scald. LaBelle *(2)* has pointed out the need for reducing bruising and post-harvest holding in order to control scald. Whittenberger and Hills *(8)* have previously pointed out the role of temperature, length of delay, and bruising of harvested cherries in causing scald.

EXPERIMENTAL

Three of the variables which were thought to affect the incidence of scald were studied during the 1954 harvest, namely, degree of bruising, and hold and soak times. Two other variables, hold and soak temperatures, were studied in the following season along with abbreviated confirming studies of the first three variables. A 5-year-old orchard of Montmorency scions on virus-free Mazzard seedling rootstock was selected as a source of fruit for the test. A complete fertilization and spray history was available for this orchard.

In order to secure replications and to allow for and discern variations during the harvest season, each series of experimental lots was repeated at weekly intervals. A group of trees was picked at each harvest in order that every lot contained fruit from several trees. Each 30-pound lot was gathered in about 15 minutes, so that the picking time was specific to within ± 8 minutes. Close supervision of picking was maintained to obtain uniform bruising between lots. Where degree of bruise was not the variable under study, a standard bruising treatment of one 30-inch drop onto a sloping surface was employed. This bruise was administered within 20 minutes of the median picking time.

Cherries were brought quickly to the proper holding time by spreading them out several cherries deep on trays in still air at the desired temperature following the bruising treatment. Soaking temperatures were monitored thermostatically and controlled to ± 2° F. by circulating cold water through solenoid valves to the ten-gallon soak tanks.

The scale of the experiment was somewhat less than that of a continuous pilot plant. Since it was necessary during harvesting to gain strict control over bruising and picking time, the size of the lot was largely governed by the amount the available help could pick in about 15 minutes. This provided sufficient fruit for all the tests of quality employed.

Special equipment used included a battery of six 10-gallon soak tanks constructed with false bottoms and overflow weirs so that cold water could be circulated in the manner common to the 5-ton capacity tanks used in the industry. Refrigeration was provided by a two-ton Freon-12 condensing unit in conjunction with a horizontal two-pass shell-and tube evaporator with refrigerant on the tube side. No eliminator was used because of the necessity for maintaining strict control over the fruit removed as pick-outs. From a sorting belt, 8 ft. long by 12 in. wide, the cherries went to a Dunkley small mechanical cherry pitter of 300 pounds per hour capacity.

Standard processing conditions were employed with only one variable changed at a time. A one-drop bruise, 4-hour hold at 80° F. and a 14-hour soak at 50° F. were selected as standard. Slight variations in these standard conditions occurred between but not within separate studies.

Cherries were packed in 307 x 409 cherry enamel cans for both canning and freezing as a most convenient size for later analysis of product quality. From each lot, six cans of cherries were hot-packed in water, and six cans were frozen with one part dry sucrose in five parts of fruit. Hot-packing consisted of a ten-minute exhaust at 180° F. followed by vacuum closing and retorting for 12 minutes at 210° F. Freezing was accomplished in still air at 0° F.

Ranges of the processing variables under study were selected to represent the extremes encountered in a survey of commercial practice. The degrees of bruising studied included an as-picked condition—which was somewhat better than is normally encountered in commercial practice, as well as more severely bruised conditions obtained from one, two, or four 30-inch drops. An unbruised lot of theoretical interest only, picked by and with the stems, was also included. Holding times ranged from the practical minimum of one-half hour up through 2, 4, 8 and 12 hours. Soaking times were 0, 2, 4, 8 and 16 hours. Holding temperatures employed were 40, 60, 80, and 105° F., and soaking temperatures were 40, 50, 60 and 70° F.

Analyses used to follow the development of scald were partly subjective and partly objective. A raw products inspector from the New York State Farm Products Inspection Service counted scalded cherries in samples of the raw product after the hold and again after the soak. Since it was felt that scald of a minor nature, not scorable under the present raw product grade *(7)*, might develop into scorable defects during post-inspection processing, both major and minor scald were determined. The dividing line between major and minor scald, based on aggregate area involved, was arbitrarily set at the area of a circle of 9/32 in. diamter. Two-pound samples were inspected, and scald was reported as the per cent by weight of cherries affected.

Likewise, an official processed foods inspector from the USDA scored the processed samples, employing the appropriate U. S. grades for the canned or frozen product. He also counted major and minor scald in 100-cherry samples of the processed product. Major scald is classed as a "blemished cherry" in that it materially affects the appearance of the cherry. For frozen cherries, major scald is further defined as affecting an aggregate area exceeding the area of a circle 9/32 in. in diameter. Minor scald affects the color score only.

An objective method was devised to measure the extent of brown discoloration in cherries showing both severe scald and oxidation. It was thought more accurate to measure the brown discoloratioin of the flesh than to measure the loss of red color from the skins alone. In this determination 500-gram samples of fresh cherries taken successively after picking, after holding, and after soaking were peeled to remove the interfering red color and blanched in boiling water to fix the existing level of brown discoloration. The cherries were then drained and blended. The color of the resulting puree was read on the Hunter color difference meter using standard plate No. 6 (NBS 54-40510 SPC 35). Brown discoloration is best expressed as the changes in brightness, or L reading, and in the saturation index, or $(a^2 + b^2)^{1/2}$.

RESULTS

In order to adequately express the degree of scald occurring in the fresh or processed product, the counts of major and minor scald are combined into an arbitrary index. In it major scald is weighted two and minor scald one so that scald index

is the sum of twice the per cent major scald plus per cent minor scald. Results of these experiments are presented in Figures 2 through 6 as scald indices for the raw product before and after soak and for both frozen and canned products. Total numerical grade scores are shown in these same graphs for both processed products to show the overall effect of the scald on quality. The changes in flesh color are tabulated in Table 1 to indicate the degree of oxidation which had occurred at the time of pitting and packing. These provide 3 independent measurements of the scald which results from changes in the 5 processing variables. All data are averages of the 3 harvests of 1954 or of the 5 harvests of 1955.

It is at once obvious that the incidence of scald experienced in the 1954 season was much higher than that obtained in 1955. The processed product grade scores in particular were much lower in 1954. This is chiefly a matter of seasonal difference. In the very dry 1954 season there was considerable sunburn and shrivelling of the fruit in the latter half of the season. Since we wanted all scalded cherries to remain in the processed product, it had been decided not to sort the fruit before pitting. Unfortunately, this resulted in a very high incidence of major blemishes, which, in turn, made separate evaluation of scald in the processed product difficult and lowered the grade score considerably. During the 1955 season a very careful sorting was practiced to avoid this difficulty. Only blemishes other than scald were removed from the product. Hence the results obtained in 1955 present more accurately the actual damage to be expected from scald. However, the trends, if not the degree of damage, experienced in 1954 are considered to be valid. The level at which the trends would actually occur is demonstrated in the confirming experiments of 1955 as shown in Table 2.

Note that scald indices of both raw and processed products rise quite drastically with increase in the degree of bruise (Figure 2). This trend is approximately linear. It is significant that unbruised fruit shows very little scald despite the relatively severe standard processing condition. On the other hand, fruit subjected to one or two drops, which is more nearly characteristic of commercially picked cherries, shows considerable damage.

Although the effect of holding time seems to be just as great as that of bruising, the increase in scald index occurs mainly in the first 4 hours and then levels off quite sharply (Figure 3). This fact is of utmost importance. It emphasizes that reduction in high-temperature holding time will reduce scald damage appreciably only if the time becomes less than 4 hours. It is convenient to refer to 4 hours' hold at 85° F. as being critical for cherries bruised to the extent usually encountered in the industry.

The rise in scald index with increased soak time is less marked than in the case of hold time (Figure 4). Although the data are somewhat scattered, it is evident that there is a tendency for scald damage to increase as soaking progresses even at the relatively low soaking temperature of 50° F.

In view of the fact that in scald and oxidation we are dealing with a diffusion process and a chemical reaction, both of which are temperature sensitive, it is not surprising to find that scald is more severe at high temperatures (Figure 5). With scald as with other diffusional and chemical processes, the rate of increase goes up as the temperature rises. The 105° F. upper limit of the holding temperatures studied is admittedly an extreme, but it is quite often approached when cherries are exposed to direct sunlight on a hot summer afternoon. It can be seen from the data that such exposure is very damaging.

Results obtained from soak temperatures in the range from the practical minimum of 40° F. to a tap-water temperature of 70° F. are not so conclusive. While processed product grade scores diminish with increasing soak temperatures, the more direct measurements of scald index and flesh color changes are

TABLE 1

Changes in cherry flesh color between picking and pitting caused by the five processing variables under study. Measured with the Hunter color difference meter and expressed as changes in brightness, L, and in saturation index, $(a^2 + b^2)^{1/2}$

Degree of bruise*	U	N	1	2	4
Changes in flesh color:					
L	+0.7	5.4	12.4	10.4	15.3
$(a^2 + b^2)^{1/2}$	0.7	3.5	4.8	3.5	2.6
Holding time, hours	½	2	4	8	12
Changes in flesh color:					
L	6.1	14.2	18.3	17.3	19.8
$(a^2 + b^2)^{1/2}$	1.1	2.4	2.6	3.5	5.8
Soaking time, hours	0	2	4	8	16
Changes in flesh color:					
L	8.6	11.4	10.2	11.4	15.8
$(a^2 + b^2)^{1/2}$	4.3	4.4	1.3	4.1	6.1
Holding temperature, ° F.		40	60	80	105
Changes in flesh color:					
L		6.3	6.6	7.6	11.4
$(a^2 + b^2)^{1/2}$		3.7	3.8	3.8	4.8
Soaking temperature, ° F.		40	50	60	70
Changes in flesh color:					
L		8.4	8.6	9.0	8.6
$(a^2 + b^2)^{1/2}$		2.9	4.5	3.2	3.4

* U = Unbruised; N = Normal bruise; 1, 2 and 4 = Number of 30 in. drops.

TABLE 2

The effect of bruising, holding time, and soaking time on processed product grade score, scald index, and changes in flesh color
1955 harvest

	Bruising		Hold time		Soak time	
	No drop	Two drops	½ hour	4 hours	4 hours	16 hours
Scald Index:						
Raw, before soak	3	33	0	26	0	10
Raw, after soak	12	89	1	58	22	37
Frozen	16	31	5	26	7	37
Canned	6	44	0	20	1	15
Change in flesh color[1]						
Change in brightness, Hunter L	5.0	10.9	0.1	9.0	3.7	8.0
Change in saturation index, Hunter $(a^2 + b^2)^{1/2}$	2.8	4.7	+0.5	3.9	2.4	4.6
Processed product grade score:						
Frozen	82.8	79.0	86.6	80.0	86.8	78.0
Canned	87.8	80.6	86.8	84.4	86.8	84.0

[1] Between picking and pitting.

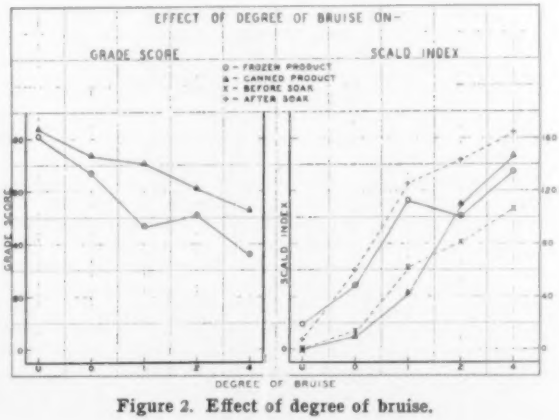

Figure 2. Effect of degree of bruise.

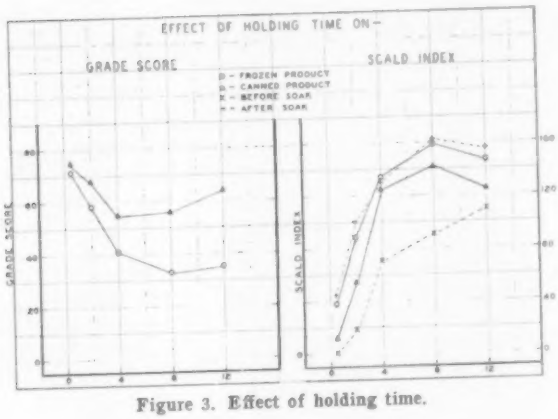

Figure 3. Effect of holding time.

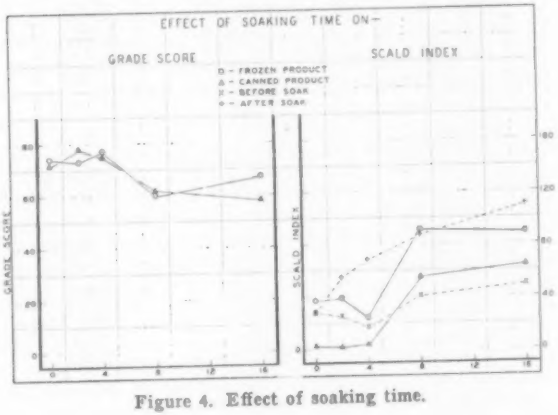

Figure 4. Effect of soaking time.

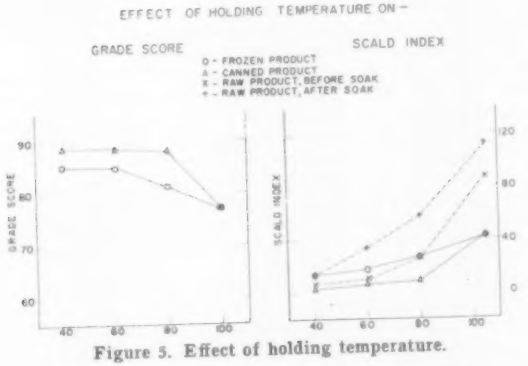
EFFECT OF HOLDING TEMPERATURE ON—
GRADE SCORE
SCALD INDEX
O - FROZEN PRODUCT
Δ - CANNED PRODUCT
X - RAW PRODUCT, BEFORE SOAK
+ - RAW PRODUCT, AFTER SOAK

Figure 5. Effect of holding temperature.

erratic and show no particular trend (Figure 6). This suggests that temperatures up to 70° F. are considerably less damaging, whether occurring during hold or soak, than temperatures of 85° F. or above.

The data were further examined from the standpoint of successive harvest dates at weekly intervals to determine if scald was more prevalent at some particular time in the season. From the data in Table 3 it can be seen that the scald index as counted in the raw product increases with the advancing season. However, this trend is not borne out by the scald index for the processed product.

DISCUSSION

It is possible from these data to estimate the relative importance of the five factors which affect the incidence of scald in red cherries. More pronounced

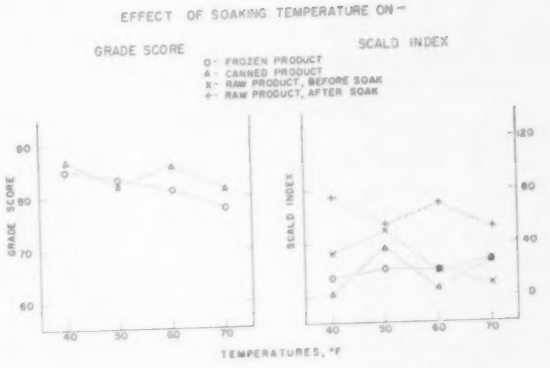

Figure 6. Effect of soaking temperature.

before the abscission layer forms tends to a greater increases in scald index were obtained from variations in degree of bruising and in time and temperature of holding in air than from normal variations in time and temperature during soaking. It follows, then, that in a normal process entailing a 4-hour hold at orchard temperature and 14 hours in cold water, the amount of scald which ensues is largely determined by the initial handling of the fruit. Once scald and oxidation are started by poor handling, i.e., excessive bruising and prolonged exposure to high ambient temperatures, cold soak water will not reverse or even halt their development. Scald and oxidation continue to develop during the soak, but more slowly because of the reduced temperature.

Actually holding and soaking differ in only two aspects. The soak period is at a lower temperature because soaking is largely a chilling operation. There is also a difference in the degree of wetness. Cherries held in lugs ordinarily stay wet with expressed juice only at points of contact with the container and between themselves. During rough handling these circular spots become slightly bruised and subsequently scald and oxidize. However, on tank-held cherries which are wet all over scald can develop wherever there is a bruise, resulting in irregular areas of scald.

The scald indices for the raw product indicate an increase in scald towards the end of the season. However, no such trend is apparent in the processed product. In general, it is believed that the excessive bruising encountered in picking immature cherries incidence of scald. Others feel, on the other hand, that as cherries become less firm in late season, they

TABLE 3

Changes in scald index through five weeks of the 1955 harvest

	July 6, 7	July 13, 14	July 20, 21	July 27, 28	Aug. 3, 4
Mean temperature, °F.	73	77	76	73	82
Raw product:					
Before soak	8	13	29	30	33
After soak	16	44	57	72	56
Processed product:					
Frozen	30	19	19	20	20
Canned	14	8	21	12	23

Each datum is an average from 14 lots, processed over a two-day period.

are more apt to bruise and subsequently to scald. We have obtained conflicting data in other studies supporting both contentions.

Some other generalizations can be drawn from the results. Since scald in the raw product was counted before and after soak, the relative importance of holding and soaking may be deduced. Considering the standard hold time of 4 hours at 80° F., and standard soak time of 14 hours at 50° F., the rise in scald index is about the same in each period. In other words, they are equally important in the development if not the initiation of cherry scald. An important, if obvious, conclusion is that scald certainly continues to develop in the soak tank despite the low temperature and lack of further bruising. It is probable that the scald which develops during the soak is initiated during the bruising and exposure to high temperature the cherries receive during the hold period.

We may also generalize in stating that under the conditions of this experiment the scald count in the processed product was less than that encountered in the raw product. This probably arises in part from the relatively strict interpretation given scald in the raw product. In addition, scald may be detected and differentiated from other types of damage on fresh cherries by its sharply delineated faded aspect much more easily than on processed fruit.

Finally, it can be seen that in almost every case the scald index is greater in frozen cherries than in the canned product. It is a matter of common agreement among processors that scald affects the frozen product more seriously. This calls attention to the fact that the rise of scald as a serious processing difficulty coincided with the rapid growth of the frozen cherry industry. Canned cherries are not so noticeably affected by scald since the pigment is released by thermal disruption and in time spreads uniformly through the cherry and among cherries in a single container. Hence, though there is probably some loss, the color at least becomes uniform. In frozen cherries, however, this process is absent and the mottled appearance remains. Oxidation is apparent as a brown cast and an off-flavor in both canned and frozen fruit, but again it is more readily noticed in the frozen product. This may be because the action of the enzyme is not so quickly checked after pitting by the relatively slow process of freezing as by the immediate enzyme destruction achieved during retorting.

It is by no means certain that all of the factors affecting scald have been uncovered. Little is currently known about scald in a physiological sense. This study has approached the problem of scald on a macro-scale, expressing its effects in terms of the gross changes which take place in the appearance of the fruit when subjected to different levels of bruising and to different holding or soaking time and temperature. The study has been successful to the extent that, in terms of variables under study, scald can be predicted, measured and reproduced with fair accuracy.

Attention is often called to differences in the incidence of scald between seasons. The influence of average temperatures during the harvest season, for example, the record warm and cool summers, respectively, of 1955 and 1956 in New York State, is very clear from the results of this study. Aside from this, however, it is felt that these differences arise very largely from the interplay of economic forces. Consideration of these factors is not included in this study.

SUMMARY

A study has been made of some processing variables which affect the incidence of scald in red tart cherries. Scald is defined as the localized loss or translocation of the red pigment from the skin of the cherry. Oxidation of the affected tissue which usually follows is regarded as a separate but related process.

The extent of damage from scald and oxidation in the frozen or canned product is largely determined by the initial handling of the fruit. This includes both the bruising which results from picking and post-harvest handling and the time-temperature product which accumulates in the interval between picking and chilling.

Fruit bruised as in normal commercial picking will usually develop severe scald if held only four hours at a normal orchard temperature of 85° F.

Soaking in cold water slows the development of scald, but it does not halt the process. Prolonged soaking is therefore not advisable if scald is obviously well started, since serious oxidation will surely follow.

Acknowledgments

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Clumping in Canned Blueberries

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CANNED BLUEBERRIES may vary from a highly attractive, free-flowing product to one that is clumped into a firm mass. Severely clumped berries are less desirable, are more difficult to use, and separation often results in torn skins and unattractive pulp. The experimental work described here was done in this laboratory in cooperation with the Western Washington Experiment Station at Puyallup, Washington. The objective was to determine the causes of clumping in canned blueberries and to seek methods to overcome this problem.

EXPERIMENTAL CANNING

Procedure. Following experimental canning of 11 varieties to enable selection of varieties with greater and less tendency to clump, Concord, Rubel, and Jersey varieties, grown in Washington *(5)*, were selected for studies of canning variables. Berries were thoroughly mixed, spread thinly on stainless-steel wire trays, sorted for removal of defects, and sampled for chemical analyses. They were thoroughly washed with water sprays, drained until nearly dry, and weighed into No. 2 fruit-enameled cans at the rate of 14 oz. (400 g.) per can. A canning sirup of 40% solids (26-2/3% sucrose and 13-1/3% dextrose) was boiled, cooled to 100° F., rechecked for density, and filled into cans at the rate of 7 oz. (200 g.) per can. Control samples were given "still cooks" in boiling water for 10 to 12 minutes with the cans in a vertical position. Representative cans from these "cooks" attained temperatures as high as 190° F. or more ¾ inch above bottom-center ("cold spot") at the start of water cooling, as determined by can-thermocouples and glass thermometers in a rack-and-pinion device. Cooling of cans to about 100° F. was done in water at about 60° F. with the cans in vertical position.[b]

Other cans were processed, as described, except that some variables were employed in heating and cooling as experimental modifications. The intermittent agitation employed was devised to simulate the action of continuous fruit cookers and coolers which pass cans along a helical path on a horizontal axis; the cans roll rapidly on their cylindrical axis only during the lower part of each loop. The minimum temperatures to which the cans needed to be cooled with agitation, to overcome clumping, were not determined. Such temperatures might be considerably above the 100° F. to which cans of fruits are frequently water-cooled, prior to air-drying.

RESULTS

As shown in Tables 1 and 2, variables which influenced the occurrence and degree of clumping of canned blueberries were variety of blueberry, agitation of cans during cooling and the severity of processing.

Effect of variety. Eleven varieties of blueberries were found to vary markedly in their tendency to clump, when compared by canning procedures in which agitation of cans was omitted. Table 1 shows that the Concord and Rubel varieties tend to clump more than the Jersey variety; other varieties also varied considerably in tendency toward clumping.

TABLE 1

Some variations in clumping of canned blueberries as affected by variety and by cooling method

Variety of blueberries	Degree of clumping			
	Non-Agitating "Cool"		Agitating "Cool"	
	1949	1950	1949	1950
Concord	++++[1]	++++		+
Rubel	+++[1]	++++	*	*
Jersey	++[1]	+	+	*
Rancocas	++	++	*	*
Grover	++			
Stanley	*	+		*
Cabot	++			
Pioneer	++++	++++		*
Katherine	++	++++		*
Atlantic		+++		*
Pemberton		++		*
(Mixed)	+++		*	

[1] Observation of 15 or more runs.
* No clumping.
\+ Slight clumping..
++ Moderate clumping.
+++ Severe clumping.
++++ Complete clumping.

Only cultivated berries of relatively large size (around ½ inch diameter), firm texture, and ripe color were employed, as these were the principal commercial or experimental varieties available in the Pacific Northwest. Wild bluberries were not included. Small-sized, clumped blueberries have been observed in commercially canned samples from other areas, which indicate that the problem of clumping is not confined to size or locality.

Effect of agitation during cooling. Agitation of cans of blueberries in sirup during water cooling to 100° F. very markedly reduced or eliminated clumping. Control cans cooled without agitation often showed severe clumping. Results are shown in Table 1. Clumping did not recur during subsequent storage at 70° F. for one year. Shaking the cans following cooling does not reduce severe clumping.

A transportation test in which blueberries were shipped approximately 4,000 miles by railroad freight produced only minor changes in clumping.

Clumping was produced in samples by still cook followed by still cool (Figure 1). These samples were then reheated to 190° F. and cooled with agitation. No clumping was observed after this treatment.

Other samples were processed by a still cook and rotary, or agitated, cooling operation. These showed no clumping (Figure 2). Upon reprocessing using still cook and still cool, clumping took place. Although

[a] Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

[b] This process is not suggested for commercial operations, because the overall heat transfer might be considerably slower and less uniform than the experimental procedure described.

TABLE 2

Effect of severity of "cook" on clumping

Variety of blueberry	Agitating "cook"	Agitating "cool"	Max. temp. reached °F.	Degree of clumping
Concord	no	no	190° F.	++++
Concord	no	no	202° F.	++++
Concord	no	no	209° F.	++++
Concord	yes	no	196° F.	++++
Rubel	no	no	182° F.	+
Rubel	no	no	192° F.	++
Rubel	no	no	199° F.	+++
Rubel	no	no	208° F.	++++
Rubel	yes	no	198° F.	++
Jersey	no	no	192° F.	+
Jersey	no	no	198° F.	++
Jersey	no	no	207° F.	+++
Jersey	yes	no	200° F.	+
Jersey	yes	no	190° F.	+
Jersey	yes	yes	190° F.	*

berries may be firmly clumped, the sirup around them will remain fluid.

Severity of processing. The severity of processing can include such factors as time, temperature, and agitation. Two different effects have been noted, of which one relates to maximum temperature and the other to physical breakdown.

If the process is measured simply in terms of maximum temperature reached, and if the berries appear not ruptured, the tendency of some berries to clump may increase with increasing maximum temperature, as shown in Table 2. These data suggest that berries with only a moderate tendency to clump will show correlation between increasing maximum temperatures and tendencies to clump.

Physical breakdown or severe rupturing of berries may release sufficient pectic materials to form continuous gel structures. A macerate of fresh berries produced by blending becomes a moderately firm gel in a few minutes. It was not a primary purpose of these experiments to study gel formation resulting from severe processing procedures as might result from the use of screw-cookers, kettles with agitators, or bulk-handling methods.

However, in a preliminary experiment Rubel blueberries in sirup were overprocessed with resulting formation of a jellied product. This material was produced simply by placing 400 g. of Rubel blueberries in a No. 2 can, covering with 40° sucrose sirup at 200° F., steam exhausting for 7 minutes, sealing, cooking with agitation for 30 minutes, and water cooling without agitation. This process was obviously excessive, and sufficient berries were ruptured and compacted to produce a gel as shown in Figure 3.

HISTOLOGICAL TESTS

Procedure. Observations were made on both fresh blueberries and on berries heated to induce clumping. Clumped berries were available from canned samples and from fresh berries heated in water in beakers to about 190° F. and cooled. Techniques included sectioning of both fresh berries and berries dehydrated in isopropyl alcohol and embedded in paraffin *(4)*. Unstained sections were examined directly with a compound microscope and photographed with panchromatic film. The outer wax-like coatings, or cutin, could be at least partially removed by chloroform. Fat-soluble dyes (such as Sudan IV) were used to differentiate the cuticle.

Results. A pronounced waxy cuticle forms the outermost portion of the skin and discontinuities or minute projections of wax structures on its outer surface produce the familiar whitish "bloom". This bloom may be removed by rinsing the berries a few minutes with chloroform (Figure 4). Underlying the bloom is a continuous wax-like layer, as shown by epidermal cross-sections (Figure 5).

Blueberries heated in water to 190° F. and still-cooled to induce clumping could sometimes be pulled apart without tearing of skins. When this was done the points at which the berries had been attached showed minute crater-like breaks in the waxy surface (Figure 6).

Sections of clumped berries, cut transversely to the points of skin attachment in clumping, revealed areas in which the waxy cuticular surfaces of adjoining berries were fused (Figure 7). Such sections as well as clumped berries could be separated in wax solvents such as ether or chloroform.

TABLE 3

Pectic constituents of blueberries

Variety	Total[1] pectin	Dry Isolated pectin	
		Methoxyl content	Anhydro-uronic acid
Rubel	0.86%	8.6%	55%
Concord	0.76	8.9	
Jersey	0.81	7.7	54

[1] Fresh weight basis.

CHEMICAL TESTS

Rubel, Concord, and Jersey blueberries were analyzed for pectic constituents. Pectin was isolated by an acid extraction at 140° F. Uronic anhydride was determined by the methods described by Leinbach *et al. (1)*. The Zeisel method was employed for determination of methoxyl content of pectin. Pectinesterase was measured by the method of MacDonnell *et al. (2)*.

Results. The results of these analyses are shown in Table 3. No correlation between clumping and pectin content is apparent.

Lipid extraction of berries was performed in the cold on berries that had been frozen, thawed, and partially dried (10 to 15% wt. loss on drying). Three

Figures 1–3. Canned blueberries: 1, badly clumped berries after still cool; 2, clumping eliminated by agitated cool; 3, overprocessed, showing both clumping and jelly formation (arrow).

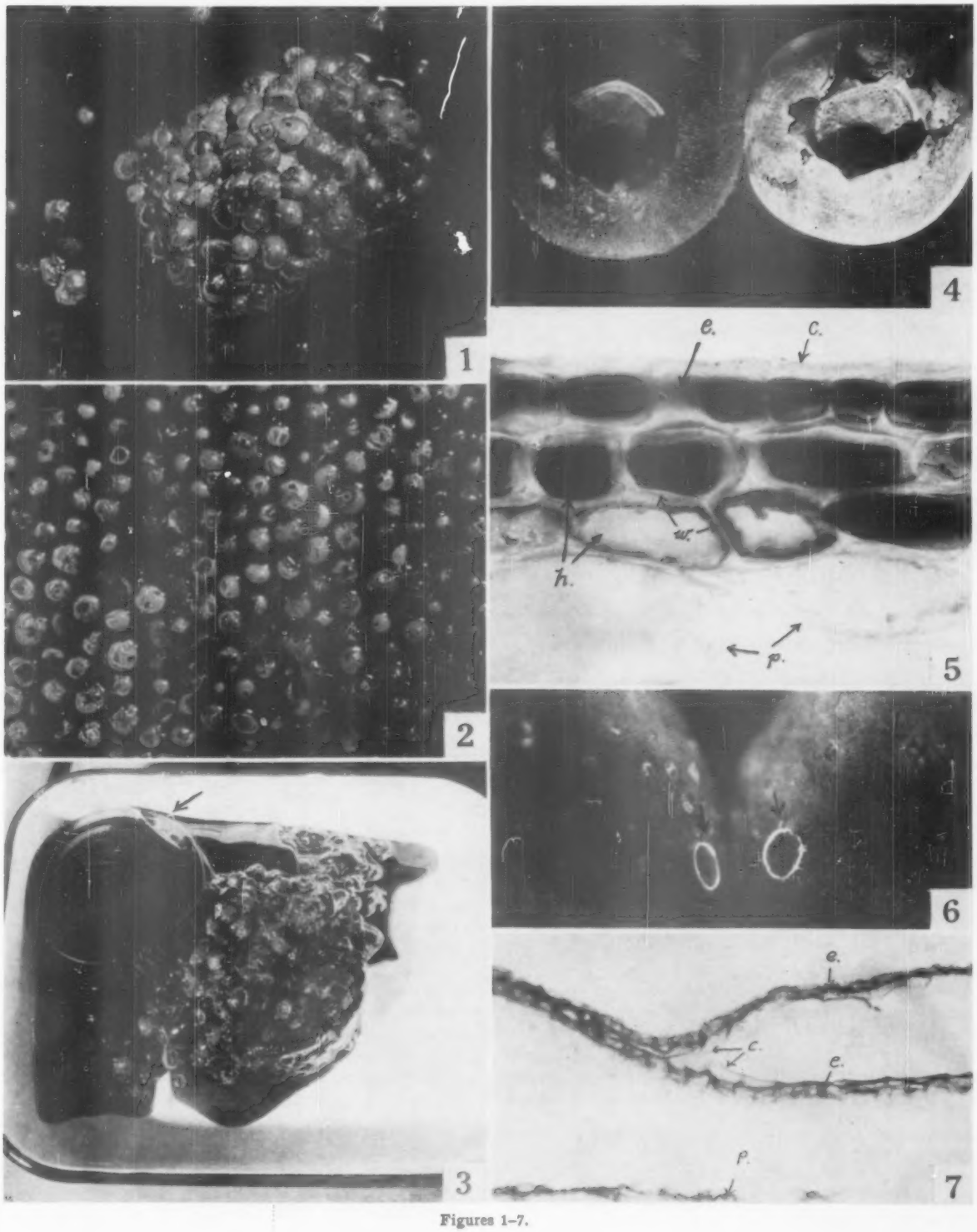
Figure 4. Whole, fresh berries, 4X magnification: the berry on the right shows the white bloom of the soft, outer wax layer while the bloom wax on the berry on the left was removed by a 2-minute chloroform rinse.

Figure 5. Photomicrograph (high magnification) of a section of the skin area of a blueberry; c, cuticular wax; e, epidermal cells; h, hypodermal cells; p, pulpy flesh cells; w, cell walls.

Figure 6. Partly separated clumped berries showing points of fusion of the surface wax (arrows) which form circular ridges when pulled apart.

Figure 7. Photomicrograph (low magnification) of skin from clumped berries: c, cuticular wax; e, partly separated epidermal layers; p, pulp tissue of one berry from which skin separated when sectioned.

different solvents, Skellysolve I, chloroform, and diethyl ether, extracted different amounts of lipids. Markley and Sando *(3)* reported extraction of waxes from cranberries with two solvents to yield different fractions of lipid material. In the work reported here, 300 g. of partially dried berries were immersed in solvent and allowed to stand 24 hours. The solvent was separated and evaporated to leave the lipid ma-



Figures 1–7.

terial. A positive correlation is apparent between tendency to clump and lipid detected by this method, as shown in Table 4.

TABLE 4

Lipid content vs. clumping of blueberry varieties

Variety	Lipid extracted, %			Clumping tendency
	Diethyl ether	Chloroform	Skellysolve F.	
Concord	0.10	0.08	0.04	+4
Rubel	0.08	.....	.....	+2
Jersey	0.05	0.05	0.02	+1

1 = least clumping.
4 = greatest degree of clumping.

SUMMARY

The tendency of some varieties of blueberries to clump when canned was studied by canning trials and by chemical and histological observations. Clumping can be greatly reduced by cooling with agitation, which apparently interferes with the binding together of berries by surface wax or cutin.

Acknowledgments

The authors are indebted to C. D. Schwartze of the Western Washington Experiment Station, Puyallup, Washington, for aid in the selection of samples, to A. D. Shepherd for suggestions in regard to pectin determination, to E. F. Jansen for suggestions in regard to pectinesterase determination, and to L. M. White for the methoxyl determinations.

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Studies on Cherry Scald

I. Relationship Between Bruising and Respiration in Water[a]

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(Manuscript received May 14, 1957)

The three major steps in the handling of cherries before the actual pitting and canning operations are harvesting, transportation to the processing plant, and tank-soaking of the fruit. This last operation has been found beneficial in allowing the fruit to cool and to become firm before being pitted. In recent years the harvested fruit has been transported from the orchards in water tanks *(8)*. This procedure serves to minimize any further bruising of the fruit following the harvesting, and enables the cooling and soaking operations to proceed even before the cherries are transferred to the soaking tanks at the plant itself. Discounting any condition that would spoil the fruit prior to harvesting, the major problem of scald (surface discoloration) arises somewhere between the picking and processing of the cherries. LaBelle *(7)* and Whittenberger and Hills *(13)* have observed that the initiation of scald is always preceded by bruising of the fruit. Commercial picking of cherries, by the very nature of the picking process, involves bruising. It was therefore decided that more information on the relationship between bruising and scald could be gained by a continued investigation of the effects of bruising and the methods of handling on the post-harvest physiology and metabolism of the fruit. Since in normal commercial operation, cherries are soaked in water after harvesting, the first experiments in this study were carried out to determine the oxygen consumption of cherries

[a] Presented at the Seventeenth Annual Meeting of IFT, Pittsburgh, Pa., May 14, 1957.

[b] One of the laboratories of the Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

in water. In the experiments both unbruised and bruised cherries were immersed in water at 10° and 30° C. The water was either half-saturated or fully saturated with oxygen.

MATERIALS AND METHODS

Materials. Montmorency cherries from the orchard of the National Agricultural College, Doylestown, Pennsylvania, were used in all of the experiments reported in this study. They were carefully cut from the trees with their stems attached and transported to the laboratory each day in a container lined with absorbent cotton to prevent bruising. Stems were later cut from the cherries so that only enough remained to be grasped by tweezers; the fruit was not handled with the fingers during any phase of the experimental procedures. Weights and volumes of the cherries were determined; the latter by water displacement. Some of the cherries were bruised by rolling them firmly between the concave surfaces of two small watch glasses. Splitting of the skin was carefully avoided in this procedure.

Methods. A Sargent Model XXI polarograph[c] was used to obtain the oxygen current-voltage curves. The cell used for the measurements consisted of a pint-sized Mason jar and a large rubber stopper through which were inserted a thermometer, a platinum wire, and a capillary tube. At the bottom of the jar was a pool of mercury into which the platinum wire extended; this served as the anode. The cathode was provided by mercury dropping through the capillary tube. The cherries were placed in the jar on top of a layer of glass beads which prevented direct contact between the cherries and the mercury. This electrolytic cell was maintained at the desired temperature by immersion in a thermostatically controlled water bath.

Potassium chloride was used as the electrolytic solution. It was diluted as much as possible (0.0001 *M.*) without affecting its conductance so that any possible influence of the dissolved salt on the physiological activity of the cherries would be minimized. Current-voltage curves obtained for dissolved oxygen in a range of diluted potassium chloride solutions showed that well-defined waves could be obtained at this low electrolyte concentration.

The procedure consisted of saturating the electrolytic solution with air by vigorous agitation for ten minutes, and then placing into this solution 30 weighed cherries of known volume. The jar was then carefully sealed by means of the rubber stopper to avoid entrapment of air bubbles over the solution. Readings were taken after an adequate period for equilibration. The oxygen content of an aliquot of the air-saturated solution was determined chemically by the Winkler method *(1)* for standardization of the polarogram. The reproducibility of the oxygen wave heights for solutions shaken for different time intervals showed that the 10-minute agitation period was sufficient for oxygen saturation. For comparison, some experiments were made after removing half of the oxygen from saturated solutions by bubbling nitrogen gas through them. Polarograms were obtained initially and at time intervals thereafter, and the corresponding wave heights converted to diffusion currents.

A typical polarogram obtained with 30 cherries in the air-saturated solution at 10° C. is shown in Figure 1. Curves A to J denote the successively dissolved O_2 contents from the beginning to the end of the experiment. Each curve shows 2 reduction waves, the first of which reached a maximum and then dropped, so that it did not provide a valid measure of oxygen content. Rather than use maximum suppressors, which may have influenced the respiration of the fruit, the wave heights of the second reduction waves were taken as the basis of the data presented since these were found to be a quantitative measure of the dissolved oxygen content.

Since previous workers had shown that the presence of metallic mercury has no inhibitory effect on the physiological activity of biological materials in water *(11)*, no precautions were taken other than to keep the cherries from direct contact with the mercury by means of the glass beads.

[c] Mention of trade name does not necessarily imply endorsement by the U. S. Department of Agriculture over similar products not mentioned.

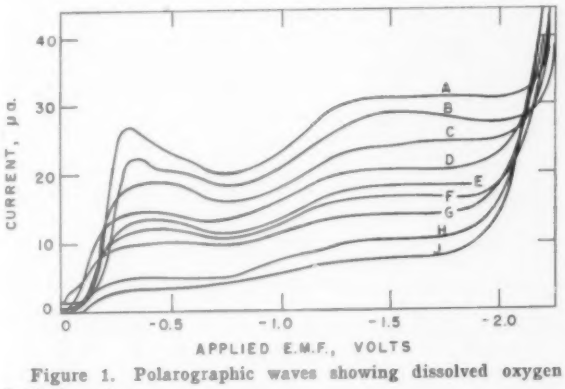

Figure 1. Polarographic waves showing dissolved oxygen levels in water.

A typical calculation of the utilization of dissolved oxygen at 10° C. by bruised cherries is shown as follows:

Total weight of 30 cherries = 95.93 g.
Total volume of 30 cherries = 88.8 ml.
Volume of stoppered cell = 415.0 ml.
Volume of 0.0001 *M.* KCl = 415.0 − 88.8 = 326.2 ml. = 0.3262 l.

Oxygen content of air-saturated solution (Winkler method) = 9.71 p.p.m. = 9.71 mg./l.

9.71 mg./l. x 0.326 l. = 3.17 mg. of oxygen available in cell.
Since 32 g. of oxygen occupies 23.2 l. at 10° C.:

$$\frac{0.00317 \text{ g.}}{32 \text{ g.}} \times 23.2 \text{ l. / mole} \times 10^6 = 2291 \ \mu\text{l. of oxygen available in cell}$$

$$\frac{2291 \text{ l.}}{95.93 \text{ g.}} = 23.9 \ \mu\text{l. of available dissolved oxygen/g. of cherry}$$

The polarographic wave height (half-wave potential of −0.90 V) at the start of the determination was 137.0 mm. (9.71 p.p.m.)

137.0 mm. = 23.9 μl. of oxygen/g. of cherry

At the end of 2 hours the wave height was 87.5 mm. (6.2 p.p.m.)

$$\frac{87.5}{137.0} \times 23.9 = 15.3 \ \mu\text{l. oxygen/g. remaining, or}$$

$$23.9 - 15.3 = 8.6 \ \mu\text{l. of oxygen consumed/g.}$$

RESULTS

Composite oxygen uptake values for unbruised cherries and cherries experimentally bruised at room temperature and immersed in water at 10° and 30° C. are shown in Figure 2, wherein it is seen that, as with other materials *(9)*, the respiratory rate increased with an increase in temperature. At the end of 4 hours the total oxygen absorbed by the unbruised cherries was 2 μl./g. at 10° C. and 10 μl./g. at 30° C. Bruising caused approximately a 5-fold increase in the oxygen uptake at 10° C. from 2.0 to 10.5 μl. of oxygen per gram, while at 30° C. the same treatment resulted in approximately a 2-fold increase, from 10.0 to 19.0 μl. of oxygen per gram.

Since 10° C. (50° F.) is the average temperature at which the water in commercial soaking tanks is maintained, it was decided to investigate the relationship between dissolved oxygen levels and the promotion of scald at this temperature. Previous studies on other plant tissues *(2, 3, 4, 12)* have shown that the respiration rate in air decreased as the available oxygen decreased. The present study showed a similar effect when cherries respired in water in which the level of oxygen continuously decreased. In Figure 3 it can be seen that the rate of respiration was related to the amount of oxygen present, and that the respiration rate decreased as oxygen was depleted. In a series of experiments in which experimentally

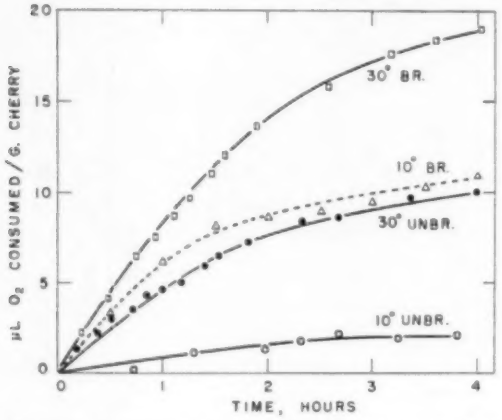

Figure 2. Oxygen consumption of bruised and unbruised red tart cherries in water at 10° and 30° C.

bruised fruit was immersed in fully aerated solutions, at the end of four hours the available dissolved oxygen was above 5 p.p.m., and no scalding was observed. When similarly bruised fruit was immersed in solutions half-saturated with dissolved oxygen, scald formation was observed after approximately 3 hours at which time the remaining oxygen concentration was usually below 3 p.p.m.

At 30° C. bruised cherries immersed in fully aerated water for 4 hours did not exhibit distinct scald spots but bleached out homogeneously over the entire cherry and became very light in color. Immersion in oxygen-deficient water accelerated this same process. It was further observed that neither high temperatures nor low oxygen levels produced scald in unbruised cherries.

THEORY

The rate of disappearance of oxygen from the aqueous solution is proportional to the concentration of dissolved oxygen and to the weight (concentration) of the cherries. This can be represented as a second-order kinetics equation:

$$-\frac{d[O_2]}{dt} = k[O_2]\ [\text{cherries}] \qquad (1)$$

Since the concentration of cherries is far in excess of the available oxygen, it can be assumed that for any given experiment, the concentration of the cherries is a constant, which can be included in the specific rate constant, resulting in the pseudo first-order equation:

$$-\frac{d[O_2]}{dt} = k'\ [O_2] \qquad (2)$$

where $k' = k\ [\text{cherries}]$

Integration of equation 2 results in the pseudo first-order equation

$$-\ln[O_2] = k\,t + C \text{ or } -\log[O_2] = \frac{k}{2.303}\,t + C' \qquad (3)$$

Therefore, a plot of the negative common logarithm of the concentration of oxygen remaining in solution against time should yield a straight line whose slope is a measure of the specific reaction rate constant for the respiration of the cherries in water at the given temperature.

That this is the case is shown in Figure 4 in which the concentrations of the oxygen remaining at any given time, expressed as negative logarithms, are plotted against time, for the respiration of 30 bruised cherries at 10 and 30° C. The slope of these linear plots yielded specific reaction rate constants of 1.58 and 8.30 x 10^{-3} per minute for the bruised cherries at 10° and 30° C., respectively, showing that the respiration of cherries in water at these temperatures follows the mathematical derivation of a pseudo first-order equation. Since the intercept of equation 3, C, was found to be zero, it was possible to

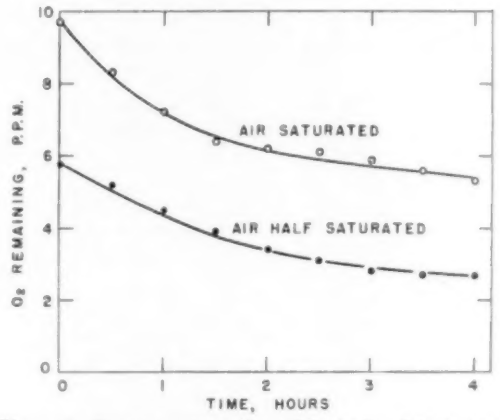

Figure 3. Oxygen consumption of bruised red tart cherries at two levels of dissolved oxygen in water.

calculate the specific reaction rate constants from the equation

$$k = 2.303\left(-\frac{\log[O_2]}{t}\right) \qquad (4)$$

The ratio of the k values for 30 and 10° C. resulted in a calculated temperature coefficient factor (Q_{10}) of 2.3 which is in good agreement with Q_{10} values reported for other fruits *(5)*.

DISCUSSION

An increase in temperature from 10° to 30° C. resulted in a 5-fold increase in the respiratory rate of the submerged cherries. This would roughly correspond to the rule-of-thumb doubling of the kinetic rate for each 10° rise in temperature. Bruising at 10° C. resulted in a 5-fold increase in respiratory rate, while at 30° C. only a 2-fold increase was noted. The observation that at either temperature the rate of respiration was increased by bruising suggests that extensive metabolic changes must have taken place. Such factors as changes in the permeability of the fruit skins and cell membranes and altered enzyme activities must be considered in order to explain the increase in oxygen utilization of the bruised fruit over that of the unbruised fruit while under water. Further, since the oxygen absorption of the bruised cherries resulted in linear pseudo-first order plots (Figure

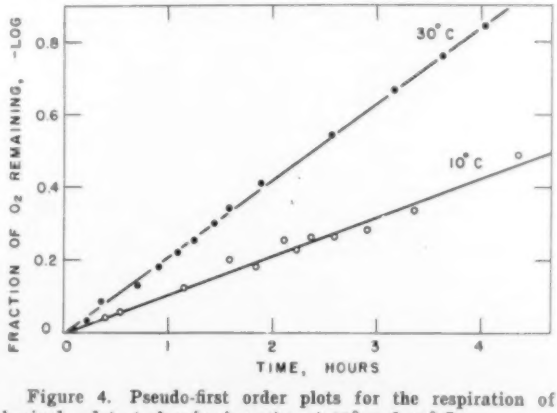

Figure 4. Pseudo-first order plots for the respiration of bruised red tart cherries in water at 10° and 30° C.

4) it would indicate that the respiration rate-determining factor at any one temperature (in the case of bruised fruit) is the availability of the dissolved oxygen.

Scald formation was also studied and the results of replicate experiments showed that bruising followed by low oxygen concentrations were contributing factors to its formation. Scald formation did not occur with bruised fruit when sufficiently high oxygen levels were maintained. The importance of oxygen availability in storage conditions of fruits was pointed out earlier by Hill *(6)*. Nelson *(10)*, who found that breakdown diseases of vegetables occurred in storage at low oxygen levels in air, suggested that the cause of these diseases may have been the internal release of toxic substances resulting from the reaction of hydrolytic enzymes with plant sugars. Since in the present study it was observed that scalding did not occur with unbruised fruit submerged in water regardless of oxygen concentration, it would appear that the initiation of scald is primarily dependent upon bruising which brings about a disruption of normal respiratory systems within the fruit.

The fact that scald was induced in the relatively short time of 3 to 4 hours in these experiments is probably due to the severe manner of bruising used on the fruit. In commercial practice, the extent of bruising resulting from the harvesting procedures no doubt runs the gamut from slight bruising to that equaling the severity of the technique used in these experiments. For this reason there is usually a longer delay in the appearance of scald in actual practice. A preliminary survey of commercial soaking and hauling tanks made during the 1956 season (unpublished data) showed that in a number of these tanks the dissolved oxygen levels were less than 2 p.p.m. The high incidence of scald observed in these tanks may have been a function of the bruising of the fruit and the fact that the oxygen concentrations had reached critical levels.

SUMMARY

A study has been made of the oxygen consumption of red tart cherries while submerged in water at 10° and 30° C. It was observed that both an elevation in temperature and bruising increased the respiratory rate. Calculation of the kinetic data for the respiratory rate of bruised cherries resulted in pseudo first order plots, showing that the rate-determining factor was the concentration of dissolved oxygen. Scald formation was observed with bruised cherries at low oxygen concentrations. At 10° C. bruised cherries scalded when the oxygen level fell below 3 p.p.m. At 30° C., however, bruised cherries scalded even in fully aerated water. The fact that unbruised cherries at these same low oxygen concentrations did not scald indicates that bruising and the consequent disruption of the normal respiratory system is the primary factor in scald formation.

Acknowledgments

The authors wish to express their gratitude to Professors David M. Purmell and Joshua Feldstein of the National Agricultural College, Doylestown, Pennsylvania, for their cooperation and aid during this study. Appreciation is also expressed to Mr. James F. Robinson for his assistance in the work.

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Studies on Cherry Scald

II. Relationship Between Bruising and Respiration in Air[a]

(Manuscript received May 23, 1957)

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LIGHT-COLORED surface discolorations on cherries, termed scald, is a serious problem of the sour cherry industry. Recent studies by Moyer *(2)*, LaBelle *(1)*, and Whittenberger and Hills *(8)* have shown that the principal cause of scald initiation is bruising, which occurs during both the picking and the post-harvest handling of the fruit.

Previous studies at this Laboratory have been concerned with the effects of bruising on the respiratory activity of cherries *(4)* and the relationship between respiration in water and scald formation *(5)*.

The present study is an investigation of the relationship between bruising and respiration in air as they influence scald formation.

MATERIALS AND METHODS

Cherries for all of the experiments were picked from several trees selected at random from the orchard of the National Agricultural College, Doylestown, Pennsylvania. The areas of the trees to which picking was limited were similar in location and height. The required number of cherries for each experiment was carefully cut by scissors from each tree on the day of the experiment and transported back to the laboratory, the entire process taking no longer than 2 hours.

Two series of experiments were made on these cherries, one to determine their respiration in air when unbruised and bruised, and one to duplicate scald in the laboratory by bruising and subjecting to high air temperatures. The respiration studies were conducted using the Warburg technique employing large, wide-mouthed respiration vessels with ground-glass reduction joints for connection to the manometers. In place of the customary center well, there were 2 hollow stopcock side arms on each flask *(6)*, each containing 0.5 ml. of 5% KOH plus a pleated 35 x 35 mm. piece of filter paper. Supports about 15 mm. from the bottom of each flask held a removable, perforated stainless steel disk for holding the cherries.

The stems were cut from the cherries so that only enough remained to be grasped by tweezers; the cherries were not handled by the fingers during any phase of the experimental procedure. Their weights and volumes were obtained, the latter by water displacement. Two cherries were dried with soft absorbent tissue and placed on the disk inside each vessel. Each vessel containing the fruit was allowed to come to equilibrium with both side stopcocks open to the center chamber. By means of a water bath the vessels were maintained at 2 temperatures, 86° F. (30° C.) and 50° F. (10° C.), the former approximating the average daytime temperature encountered in the orchard, and the latter the temperature of commercial soaking tanks.

Oxygen uptake of each pair of cherries was measured first. Side stopcocks were then carefully closed off from the central chamber with the vessels still in a stationary position in the water bath, and the total gaseous exchange (O_2 plus CO_2) measured. Values for the oxygen and carbon dioxide exchanges were then calculated *(7)*.

Respiratory activities were determined first on the normal fruit and then on the same cherries following bruising. In this manner each set of cherries served as its own control. The cherries were bruised by dropping them from a height of 3 feet onto a hard surface. Care was taken to avoid splitting the skins.

In the second series of experiments, typical lug scald was induced in the cherries in the laboratory by bruising them and storing them at high temperatures comparable to those frequently encountered in the orchard. The cherries were dropped from a height of 3 ft. onto a hard surface 1, 2, 3, or 4 times and then held in a glass container at 90° F. (32° C.) for up to 5 hr. Since the scald spots thus induced did not usually appear immediately, the cherries were soaked overnight in water at 35° F., whereupon the blemishes became quite evident and could be counted easily. (Soaking 6 to 12 hr. before processing is common procedure in the industry.) Each lot treated in this way consisted of 25 to 30 cherries, and the percentage of each lot slightly scalded (partially bleached surface areas) and severely scalded (completely bleached areas at least ¼ in. in diameter) was recorded.

RESULTS AND DISCUSSION

Quantities of oxygen consumed and carbon dioxide evolved by cherries respiring in air at 10° C. (50° F.) are shown in Figure 1. For unbruised fruit the average respiratory quotient (R.Q.) was 0.9. Bruising caused an average increase of 9% in the oxygen consumption and the carbon dioxide output rose by approximately 33% giving an R.Q. of 1.1.

At 30° C. (86° F.) the quantities of oxygen utilized and carbon dioxide evolved (Figure 2) showed an appreciable increase. The oxygen consumption increased from 18.9 μl./g./hr. at 10° C. to 46.6 μl./g./hr. at 30° C., and the carbon dioxide output increased from 17.2 μl./g./hr. to 48.2 μl./g./hr. The ratio of the oxygen consumption of unbruised fruit at 10° and 30° C. was 2.46 corresponding to a calculated Q_{10} value of 1.57, a normal value for enzyme-catalyzed reactions. For unbruised fruit the average R.Q. was 1.0. Bruising caused an average increase of 27% in the oxygen consumption and 63% in the carbon dioxide output, giving an R.Q. of 1.3.

In a series of studies being carried out in this Laboratory (unpublished data) it has been noted that

[a] Presented at Seventeenth Annual Meeting of IFT, Pittsburgh, Pa., May 14, 1957.

[b] One of the laboratories of the Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

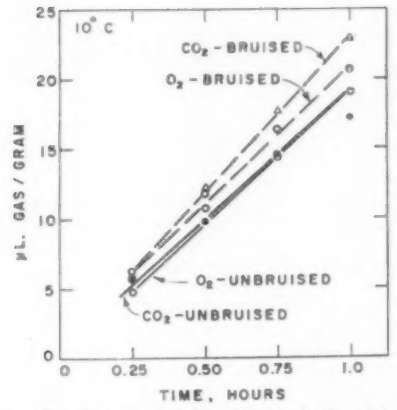

Figure 1. Respiratory activity of unbruised and bruised red tart cherries in air at 10° C.

the respiratory activities of red tart cherries from one orchard has been similar so far for the seasons of 1956 and 1957. The probability that geographical location may exert a notable effect on the respiratory effect as well as on the response to bruising is suggested in a report on cherries grown in the Biglerville, Pa., area *(4)* which showed an increase in oxygen consumption and carbon dioxide evolution of 50% and 126%, respectively, after bruising. These cherries also had higher R.Q. values, both bruised and unbruised, than the cherries reported in this study.

In order to provide more information on scald development, experiments were carried out relating scald to the extent of bruising and to the time and method of holding cherries in air at a higher temperature following bruising.

Table 1 shows that the incidence and severity of scald in cherries held at a high temperature were related to the amount of bruising.

Table 2 shows that after the bruised cherries were held in air at 90° F. for 2 hours scald was evident on all the cherries but most of it was slight, and that severe scald appeared in half of the bruised cherries held for 5 hr. To determine the possible effect of the conditions under which cherries are held after bruising, a further experiment was performed in which the cherries, instead of being placed on top of each other in a container, were placed on a wire screen in a single layer. As Table 2 shows, with this procedure scald was completely eliminated in more than half of the cherries, while the rest were for the most part only slightly scalded. Examination of the cherries held in the container and those held on the screen showed that in each case scald occurred only at points of contact. The scald was much more extensive in the cherries held in the container where there were many points of contact between the cherries and the container. Similarly, the scald was restricted greatly where each cherry had only minute points of contact with the meshes of the screen.

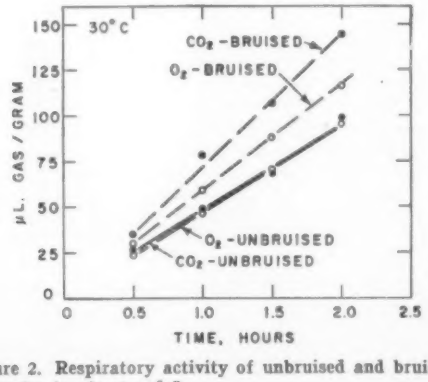

Figure 2. Respiratory activity of unbruised and bruised red tart cherries in air at 30° C.

TABLE 1

Effect of the extent of bruising on the formation of scald in bruised cherries
(Cherries held in container 5 hr. at 90° F.)

No. of 3-ft. drops	% of cherries		
	No scald	Slight scald	Severe scald
0	100	0	0
1	68	32	0
2	36	60	4
3	0	52	48
4	4	48	48

Thus, the similarity between lug scald and tank scald, as described in a separate publication *(5)* can be established. In the present case it appears that points of contact between cherries and the container or other cherries would have little or no oxygen supply. At these points of contact, or in the wet environment, gas exchange was curtailed sharply, oxygen supply was limited, and a shift in respiration took place. Scald formation therefore appears to be due to a lack of oxygen, or to the liberation or accumulation of toxic substances *(3)* that may occur as a result of an inadequate oxygen supply.

TABLE 2

Effect of time and conditions of holding on the formation of scald in bruised cherries
(Cherries dropped 3 times from 3-ft. height)

Held at 90° F. (hr.)		% of cherries		
In glass container	On wire screen	No scald	Slight scald	Severe scald
0	..	100	0	0
2	..	0	65	35
5	..	0	50	50
..	5	56	38	8

SUMMARY

Unbruised red tart cherries respiring in air gave a respiratory quotient of 0.9 at 10° C. and of 1.0 at 30° C. Raising the temperature from 10° to 30° C. caused nearly a three-fold increase in the oxygen consumption of unbruised fruit. Under conditions of stress such as bruising, the oxygen consumption and carbon dioxide evolution rose at either temperature.

Bruised cherries stored in air at 90° F. for only 2 hours scalded at the points of contact between cherries, and between cherries and container. Scald development was correlated with the extent of bruising and with the length of the delay period after bruising.

Acknowledgment

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Comparative Effectiveness of Tetracycline Antibiotics for Fish Preservation[a]

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(Manuscript received May 15, 1957)

Independent investigations conducted in two widely-separated laboratories six or seven years ago *(5, 11, 12)* showed that the most satisfactory antibiotics for flesh food preservation were, in decreasing order of effectiveness, chlortetracycline (CTC), oxytetracycline (OTC) and chloromycetin. In view of these results, subsequent research in this field was largely carried out with CTC. However, the recent approval for use of CTC for poultry preservation in the United States and Canada, and for fish preservation in Canada, has undoubtedly stimulated interest in further possible applications of antibiotics for food use. This in turn has led to a need for further detailed research on the comparative effectiveness of tetracycline antibiotics for flesh food preservation. In general, the more recent comparative studies with poultry *(1, 6)* and with fish *(3, 13)* have shown that CTC is a more effective preservative than OTC or tetracycline (TC), though recent studies in which salmon were stored in cooled sea water indicated that the three tetracycline antibiotics possessed similar activity *(7, 8)*. Since our own early comparative data with CTC and OTC were somewhat limited *(12)*, and since we had only conducted a few tests with TC, a comparative study of the effectiveness of the three tetracycline antibiotics was made.[b]

EXPERIMENTAL PROCEDURES

The antibiotics were compared under 3 different conditions of application as follows. Lingcod *(Ophiodon elongatus)* were used in most experiments as these fish spoil more rapidly than certain other commercially used North Pacific fish.

Treatment of fillets. Fish were filleted under clean conditions, the fillets skinned and pieces of fairly uniform size were then prepared. The latter were dipped 1 minute in water with and without 5 p.p.m. of tetracycline antibiotic, drained for 2 minutes on clean, wire racks, and stored at 0°, 4° or 10° C. in polyethylene bags. A single fillet was examined at each sampling interval.

Storage of eviscerated fish in ice. Ice containing CTC, OTC and TC was prepared in 300-lb. blocks in a commercial ice plant using carboxymethylcellulose as distributing agent *(2, 4)*. Each block received a mixture consisting of carboxymethylcellulose (Hercules "High Viscosity 70" <100 mesh), C.P. sodium chloride and clinical grades of the antibiotics as hydro-

[a] Presented at the Seventeenth Annual Meeting of the Institute of Food Technologists, Pittsburgh, Pennsylvania, May 15, 1957.

[b] Since this paper was presented the more recent literature on use of antibiotics in fish preservation has been reviewed *(10)*.

chlorides in amounts sufficient to give final concentrations of 100, 300 and 5.0 p.p.m., respectively. Strictly fresh fish, usually in *rigor mortis*, were used in these and subsequent experiments. They were lightly rinsed in fresh water, and were then iced in insulated clean galvanized boxes. At intervals a single fish was removed, filleted on clean paper, and the fillets stored 18 hr. at 10° C. in closed polyethylene bags in order to accelerate bacterial spoilage.

Storage of eviscerated fish in refrigerated brine. Sea water which is maintained at about −1° C. has been found to be an excellent means of maintaining the quality of fresh fish during transport and storage (*9*). In the present work, since full strength sea water was not readily available, 3% solutions of sodium chloride with and without 1.5 p.p.m. of the tetracycline antibiotics were used. Twenty-litre portions were added to large, covered plastic containers, eviscerated fish immersed therein, and the temperature maintained between −1° and 0° C. In one experiment a stream of air was slowly bubbled through the solutions in an attempt to counteract the anaerobic conditions which prevail under these storage conditions. Sampling and incubation techniques were the same as those used with the iced fish.

Bacterial counts. Direct counts were made by the procedure used routinely in this laboratory. For viable counts dilutions of the blended flesh were made using 3% sodium chloride solution. Bacto nutrient agar containing 3% sodium chloride was used for preparation of the plates and an incubation period of 2 days at 25° C. was employed.

RESULTS AND DISCUSSION

The experiments were designed purposely to maintain the antibiotic concentrations used at fairly low levels such as would be consistent with general commercial practice. Results obtained in the fillet dipping experiments (Tables 1, 2 and 3) show that CTC was considerably and consistently more effective than either OTC or TC, irrespective of the storage temperatures employed. Ice containing CTC proved more effective than ices containing OTC or TC as evidenced by both lower direct and viable bacterial counts and by odour of the fish (Table 4).

Results in the case of the chilled salt solution storage experiments were complicated and somewhat confusing. The first experiment, in which rock cod (*Sebastodes* sp.) were stored in non-aerated solutions (Table 5), brings out several important facts. There was, in the first place, no consistent agreement between the total and viable bacterial counts, though the direct counts were always higher. All 3 tetracycline antibiotics gave protection against development of unpleasant off odors, the improvement here being more marked at the 21-day storage interval with CTC than with OTC or TC. With CTC the direct bacterial counts were somewhat lower than those of the control fish, but no important differences in viable counts were detected. With both OTC and TC the viable counts were consistently higher than those of the controls.

Another similar experiment (Table 6) was made with lingcod in order to ascertain the possible influence of aeration on the effectiveness of CTC. The results showed a definite organoleptic and bacteriological improvement which, as far as the former was concerned, continued until the fish had been stored

TABLE 1

Effect of various antibiotic treatments on the bacterial content of lingcod fillets stored at 0° C. (32° F.)

Days stored	Bacteria per g. (x 10⁶) by direct count after immersing fillets in the following solutions			
	H_2O	5 p.p.m. CTC	5 p.p.m. OTC	5 p.p.m TC
5	<0.5	<0.5	<0.5	<0.5
8	13	<0.5	5	7
12	190	43	230	180
15	230	70	270	380

TABLE 2

Effect of various antibiotic treatments on the bacterial content of lingcod fillets stored at 3° C. (37.5° F.)

Days stored	Bacteria per g. (x 10⁶) by direct count after immersing fillets in the following solutions			
	H_2O	5 p.p.m. CTC	5 p.p.m. OTC	5 p.p.m TC
7	130	4.8	77	66
8	330	31	160	94
10	480	65	450	380
13	430	230	370	430

TABLE 3

Effect of various antibiotic treatments on the bacterial content of lingcod fillets stored at 10° C. (50° F.)

Days stored	Bacteria per g. (x 10⁶) by direct count after immersing fillets in the following solutions			
	H_2O	5 p.p.m. CTC	5 p.p.m. OTC	5 p.p.m TC
4	110	14	65	54
5	650	81	620	480
6		100	700	690

TABLE 4

Effect of storage of eviscerated lingcod in ordinary ice and ice containing antibiotics on their total and viable bacterial content and odour

Days stored	Bacteria per g. (x 10⁶) and odour ratings[1]							
	No additive		5 p.p.m. CTC		5 p.p.m. OTC		5 p.p.m. TC	
	Direct count	Viable count	Direct count	Viable count	Direct count	Viable count	Direct count	Viable count
14	270 stale	47	6.9 fresh	1.4	81 fresh	22	91 fresh	
17	390 stale	30	30 very slightly stale	3.8	230 slightly stale	17	220 slightly stale	27
20	420 extremely putrid	46	86 slightly stale	10	210 putrid	91	250 putrid	120

[1] The following arbitrary odour rating in order of preference has been employed in this and subsequent tables: fresh<very slightly stale <slightly stale<stale<putrid<extremely putrid.

TABLE 5

Effect of storage of eviscerated rock cod at −1° to 0° C. in 3% NaCl solutions, with and without added antibiotics, on their total and viable bacterial content and odour

Days stored	Bacteria per g. (x 10⁶) and odour rating							
	No additive		1.5 p.p.m. CTC		1.5 p.p.m. OTC		1.5 p.p.m. TC	
	Direct count	Viable count	Direct count	Viable count	Direct count	Viable count	Direct count	Viable count
21	49 extremely putrid	0.80	21 fresh	0.15	49 slightly stale	8.8	54 slightly stale	17
25	73 extremely putrid	0.74	24 slightly stale	0.89	53 slightly stale	5.6	52 slightly stale	13
28	84 extremely putrid	0.71	23 stale	0.90	62 stale	16	58 stale	18

TABLE 6

Effect of storage of eviscerated rock cod at −1 to 0° C. in aerated and non-aerated 3% NaCl solutions, with and without added CTC, on their total bacterial content and odour

Days stored	Bacteria per g. (x 10^6) and odour rating			
	No additive, non-aerated	No additive, aerated	1.5 p.p.m. CTC non-aerated	1.5 p.p.m. CTC aerated
13	42 extremely putrid	150 putrid	4.5 fresh	3.1 fresh
15	29 extremely putrid	46 putrid	28 fresh	26 fresh
16	20 extremely putrid	88 putrid	21 fresh	15 fresh
17	46 extremely putrid	55 putrid	5.3 fresh	44 fresh
20	95 extremely putrid	80 extremely putrid	98 fresh	130 fresh

20 days. Total bacterial populations were, in general, lower with fish stored in the CTC brine, but the spectacular differences encountered in the fillet dipping tests were not demonstrable. Aeration did not exert any important effect, but this technique may not have been sufficient to change the rather anaerobic conditions which appear to exist in the fish themselves.

Overall results of these trials definitely demonstrate the superiority of CTC over OTC and TC when these are applied in fillet dipping or fish icing procedures. Results with 3% salt solution storage also tend to demonstrate the somewhat greater effectiveness of CTC. However, under this latter condition the whole spoilage picture appears to be complicated. Thus, the high total bacterial counts as compared with the low viable counts indicate that bacteria may be rapidly dying off. Spoilage in chilled salt solutions is characterized by development of unpleasant and characteristic odors which suggest presence of diethyl sulfide and hydrogen sulfide. Further experiments have been initiated in order to examine more thoroughly the changes which occur in fish held in this comparatively anaerobic environment, and in these anaerobic viable bacterial counts will also be made.

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Penetration of Maltosaccharides into Processed Clingstone Peaches*

(Manuscript received October 18, 1957)

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MANY FACTORS APPEAR TO AFFECT the penetration of sugars into a canned fruit product: type of fruit, processing conditions, composition of the syrup, etc. Although some of these factors have been studied already, uncertainties still exist regarding the relationship between sugar penetration and the molecular size of the sugar species present in the syrup.

Syrups used in canning fruit products are based mainly on sucrose, but up to 25% of the dry solids weight in these syrups may be derived from corn syrup. Because corn syrup is made by hydrolysis of corn starch, it has a wide variation in composition: sugars, from glucose up through the maltosaccharides to starch, are present in varying amounts.

Penetration of the sugars from the syrup into the fruit is probably related to the diffusional properties of the individual sugars. Little work has been done on the diffusion of the sugars that are normally present in a canning syrup other than glucose, maltose, and sucrose *(1, 10, 16, 18)*. The effect of concentration on the diffusion coefficient has been studied *(7, 12)* with the result that the coefficient was found to decrease with increasing concentration. Clarke and Dole *(6)* found the diffusion coefficient of sucrose in the presence of glucose to be relatively greater than corresponding values in the pure sucrose-water system at the same total sugar concentration. However, it was noted that with an increasing concentration of glucose, the diffusion coefficient of sucrose decreased more than did the diffusion coefficient of glucose in a glucose-water system.

All the diffusion studies reported above have been conducted in model systems of two or three components: water and one or two sugars. Unfortunately, because of the many components present in canned fruits, these theoretical findings cannot be directly applied to the problem of sugar penetration here.

This study was designed to examine the rate of penetration of the various components of corn syrup in canned clingstone peach halves. The primary design consisted of adding, to series of cans with a 40° Brix cover syrup, a small portion of one of the syrup's component sugars as a C^{14}-labeled molecule. It was assumed that the movement of the radioactive component in the syrup and in the peach reflects the movement of the whole of that component.

METHODS AND MATERIALS

Preparation of C^{14} labeled sugars. The C^{14} labeled starch was prepared with tobacco leaves *(5)*, starch carrier added, and the mixture hydrolyzed by previously described methods *(5, 15)*. $Ba(OH)_2$ was subsituted for $BaCO_3$ in neutralization. Separation of the sugars was accomplished by modification of the methods of Jeanes *et al. (13)*, with streaking of the sugar solution across the top of Whatman No. 1 filter paper, and using 5 developments in isoamyl alcohol, pyridine and water (1:1:1). The radioactivity of the streak amounted to about 20,000 counts per minute on a Tracerlab Monitor, equivalent to about 10–20 mg. of sugar per sheet of paper.

The various radioactive bands were located by placing the dry chromatogram face down on Kodak No-Screen X-ray safety film, stapling film and chromatogram together at the corners, and exposing the film for about 24 hours. After removal of the chromatogram, the film was developed (Figure 1). The film and chromatogram were matched and aligned by means of the staple holes and the assembly placed on a glass table top with lighting under the glass. The bands of radioactive material were outlined in pencil on the chromatogram. These outlined bands were then cut from the chromatogram and separately suspended in a small chromatography cabinet. The sugars were

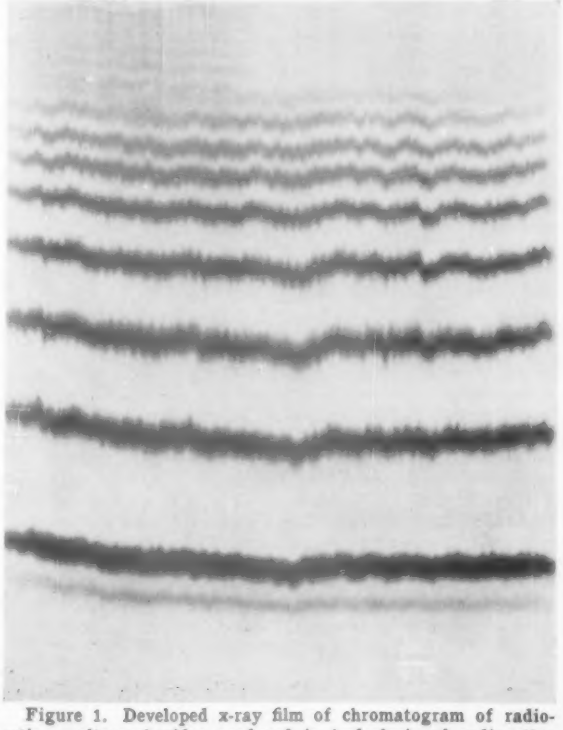

Figure 1. Developed x-ray film of chromatogram of radioactive maltosaccharides produced in hydrolysis of radioactive starch. Note identifying staple holes in corners.

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eluted with distilled water containing a very small amount of $HgCl_2$ and collected in 30 ml. beakers. The bands eluted were D.P. 1–5 as individual, pure fractions, and D.P. 6 and higher were taken as a single mixed fraction. (D.P. refers to the "degree of polymerization," i.e., the number of 1–4 linked glucose units in a sugar molecule).

Identification of the various sugars was accomplished by plotting the log of the total distance moved by each sugar band against the number of glucose units in the sugar molecule *(2, 3, 4, 8, 9, 13)*. The relationship of log apparent R_f vs. D.P. was rectilinear for all chromatograms.

Preparation of the sample. Syrup of 40° Brix (75% sucrose and 25% 42 D.E. corn syrup[b] on a dry solids basis) was prepared. The syrup was divided into 6 aliquots, and to each aliquot was added one of the C^{14}-labeled sugars (D.P. 1, 2, 3, 4, 5, and 6+). In no case did the added component exceed 10 mg. per 530 ml. aliquot of syrup. These syrups were examined for composition (chromatography) and for radioactivity (combustion) before being added to the cans.

Johnson clingstone peaches were hand-pitted, lye-peeled, and closely inspected for cracks in the pit area. Only those peaches which showed no pit area damage were used. The peach halves were then weighed, and the single halves were placed each in a 207 x 301 can with the pit down. Seventy-five ml. of a syrup were added to each can. A total of 42 cans was prepared so that six C^{14}-labeled sugar fractions were examined over 7 sampling periods. The sample periods were zero time (immediately after canning), 1½, 3, 5, 10, 30, and 60 days.

Cans were processed in boiling water for 24 minutes and cooled in cold water. After the 0 time sample was taken, the remainder of the cans was stored at 70° F. The cans in the storage room were hand-rotated each day of storage to insure that no local differences in sugar concentration occurred.

Sample analysis

Syrup. The syrup was poured from the can, its volume measured, and the Brix value determined. A sample of each of the syrup variations was chromatographed to determine the effect of processing on syrup composition. The syrup was then frozen and stored at −18° C. until needed. For determination of radioactivity the frozen syrup samples were oxidized to CO_2, which was collected and precipitated as $BaCO_3$ *(11)*. The sample radioactivity was determined in a windowless flow counter and recorded on a Tracerlab Auto-Scaler. The activities were corrected for self absorption to zero thickness as per Karnovsky, *et al. (14)*.

Peach. The peach half was blotted dry and a 3 cm. wide slice cut from side to side through the center of the peach. This center portion was again blotted dry and cut into eight radial slabs about 6 mm. thick. Further cuts isolated radial sections 6 mm. wide, 6 mm. thick and about 2–3 cm. long. The pieces were frozen in aluminum dishes floating on a dry ice-acetone bath.

Lyophilization was carried out with the specimen tubes immersed in an ethylene glycol-water bath maintained at −30° C. and with a liquid nitrogen moisture trap. A vacuum pump and an oil diffusion pump in series were used to produce an absolute pressure of about 5–10 μ Hg, as measured with a Pirani gauge. The lyophilization process was completed in 74 hours.

The method of Sterling and Chichester *(17)* was used to prepare the peach specimens for radioautography. Radial sections were cut at 15μ. Following the method of Sterling and Chichester *(17)*, a cover slip with a mounted section was allowed to irradiate a nuclear track plate for the determination of the location of the radioactive sugars with respect to cellular structure. A duplicate section was allowed to irradiate a second nuclear track plate (for about 6 times the length of the first exposure) for an optical density determination.

The optical density of the nuclear track plates was measured with an Applied Research Laboratory Microdensitometer, and the readings were taken as per cent transmission.

Readings were made at 0.5 mm. distances along the radial axis from skin end to pit end of the peach specimen. A series of 5 readings was taken tangentially across the width of the section at each radial position and averaged for that setting. Each time the radial setting was changed the instrument was checked and reset if necessary.

A complete experimental set of 6 sugar samples over 7 sampling periods was measured. A second set of 7 sample periods of D.P. 6+ with different peach sections was found to correspond with the original.

[b] From information furnished by the Corn Industries Research Foundation, the composition of the syrup solids here was determined to be as follows:

Sucrose	75%
D.P. 1	4.2%
D.P. 2	3.3%
D.P. 3	2.8%
D.P. 4	2.4%
D.P. 5	2.1%
D.P. 6 and above	10.0%

EXPERIMENTAL RESULTS

Syrup analysis. Chromatograms of the various syrups before and after canning were virtually identical. When the X-ray film was exposed to the chromatograph, only one radioactive spot appeared with each syrup. Therefore there was no noticeable hydrolysis or breakdown of glucose or the various identifiable maltosaccharides during heat processing or subsequent storage.

The results of the analysis of the various syrups are given in Table 1. This table shows volume and Brix value of the syrup and the radioactivity, total amount, and concentration of the individual sugars in the syrup.[c] Figure 2 shows the change in average syrup volume with time, obtained from Table 1.

The total amount and concentration of each component of the syrups tended to decrease with increase in storage time. The concentration of D.P. 1–3 reached essentially a constant value after 1½ days while the concentration of D.P.'s 4 and 5 required about 5 days. That of D.P. 6+ did not become con-

[c] The concentration of any particular D.P. present in the syrup was considered as: (Brix value in g./100 ml.) x (relative amount of that sugar in original syrup) x (proportion of original amount of that sugar remaining in syrup as determined by syrup combustions).

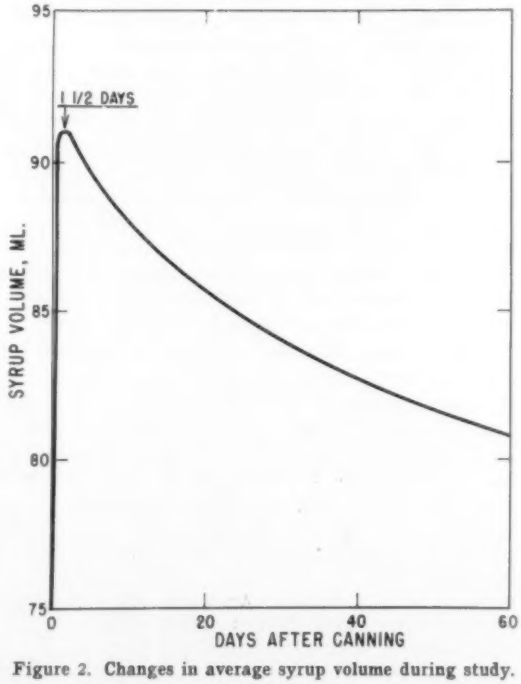

Figure 2. Changes in average syrup volume during study.

TABLE 1

Composition of syrup

Sample		Days storage							
		Orig.	0	1½	3	5	10	30	60
DP1	Volume (mls.)	75	82	91	86	91	94	82	78
	Brix	39.8	33.2	28.6	27.9	27.1	25.3	25.8	27.7
	Radioactivity[1]	223	187	171	174	171	172	175	185
	Total amount[2]	1.19	0.92	0.79	0.75	0.75	0.73	0.66	0.72
	Concentration[3]	15.9	11.2	8.7	8.7	8.3	7.6	8.0	9.2
DP2	Volume (mls.)	75	80	93	91	86	87	79	83
	Brix	39.7	31.9	26.9	27.9	27.7	26.5	27.3	26.0
	Radioactivity	120	110	98	92	96	95	96	95
	Total amount	0.99	0.78	0.68	0.65	0.63	0.60	0.57	0.57
	Concentration	13.1	9.7	7.3	7.1	7.3	6.9	7.2	6.8
DP3	Volume (mls.)	75	78	89	89	90	89	83	81
	Brix	39.7	32.2	27.2	26.7	27.9	25.2	25.9	26.3
	Radioactivity	108	103	95	89	82	88	87	88
	Total amount	0.84	0.67	0.60	0.55	0.54	0.51	0.48	0.49
	Concentration	11.1	8.5	6.7	6.1	5.9	5.7	5.8	6.0
DP4	Volume (mls.)	75	78	89	90	91	88	88	87
	Brix	39.8	32.9	27.2	27.7	26.2	25.7	24.7	24.5
	Radioactivity	100	98	87	77	77	71	68	75
	Total amount	0.72	0.61	0.51	0.46	0.44	0.39	0.36	0.39
	Concentration	9.5	7.8	5.7	5.1	4.8	4.4	4.0	4.4
DP5	Volume (mls.)	75	81	92	90	89	88	87	75
	Brix	39.6	32.7	28.7	27.1	25.2	24.9	25.6	27.0
	Radioactivity	83	80	72	72	73	70	68	60
	Total amount	0.63	0.54	0.48	0.45	0.42	0.39	0.38	0.31
	Concentration	8.3	6.7	5.2	4.9	4.7	4.5	4.4	4.1
DP6+	Volume (mls.)	75	80	92	93	93	83	84	83
	Brix	40.0	31.7	26.7	27.6	25.2	27.4	25.7	25.4
	Radioactivity	544	455	429	403	391	372	340	356
	Total amount	3.0	2.13	1.97	1.90	1.69	1.57	1.36	1.45
	Concentration	40.0	26.6	21.4	20.5	18.2	18.9	16.2	17.5

[1] Radioactivity reported as counts per minutes per mg. $BaCO_3$.
[2] Total amount of the DP indicated, in grams.
[3] Concentration of the DP indicated, in mg. per ml. syrup.

stant until about 30 days. The total amount of each component followed roughly the same pattern. The initial relative drop in both concentration and total amount during canning decreased with increasing D.P. except for D.P. 6+ where a very high initial concentration was present.

Histology. The peach sections, after being stained and mounted over the developed nuclear track plate, permitted examination of sugar distribution at the cellular level. The sugar concentrations appeared to be equal within the cells and between the cells at any given point in the peach. However, higher sugar concentrations occurred within the vascular bundles as compared to the peach tissue adjacent to these vascular bundles.

Microdensitometry. A typical image produced by the peach section on the nuclear track plates is shown in Figure 3. Sample densitometer readings are summarized graphically in Figures 4–7, where the relative concentration is plotted against distance into the peach from skin end to center, and pit end to center. The breaks in the curves are due to differences in the thickness of the various peach samples. It appears that the rate of penetration of the various sugars into the peach is inversely related to the D.P. of the individual sugar. The differences in the initial rates of penetration are shown in Figure 4. The change in distribution of D.P. 1 (glucose) with storage time is shown in Figure 5. It may be seen that some radioactive sugar occurred throughout the entire peach at zero time. For D.P. 6+, Figure 6, and the other sugars complete penetration occurs by 1½ days.

The rate of attainment of nearly uniform concentration on each side of the peach also varied with the D.P. as follows:

D.P.	*Skin End*	*Pit End*
1	5 days	10–30 days
2	10 days	30–60 days
3	60 days	over 60
4, 5, 6+	over 60	over 60

After a near uniform concentration throughout the peach occurs in the sugars of lower D.P., this concentration gradually increases with time. There may still be a concentration gradient from the surface of the peach to the interior, but this could not be measured with the techniques available.

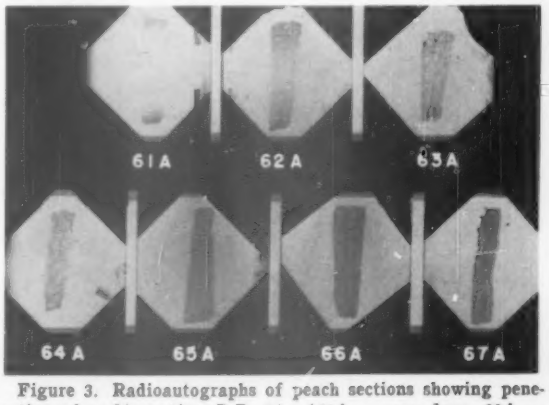

Figure 3. Radioautographs of peach sections showing penetration of radioactive D.P. 6+. (61A — zero days, 62A — 1½ days, 63A — 3 days, 64A — 5 days, 65A — 10 days, 66 A — 30 days and 67A — 60 days).

Uniform concentration was not attained with the 3 sugars of higher D.P. (4–6+), even at 60 days. Figure 7 indicates the presence of a concentration gradient in these samples at 60 days. Thus, an apparently uniform concentration gradient was achieved with D.P. 6+ (Figure 6) at 10 days; yet this was disturbed at 30 and 60 days in opposite fashions. It is also to be noted that the concentration at zero depth at the skin and pit end differ quite markedly; yet, it would be expected that since the concentration of the syrup is uniform, concentration at zero depth should be uniform. This concentration difference perhaps may be due to the technique of measurement.

DISCUSSION

The histological studies indicate that the sugar movement into the peach occurs in mass and not between the cells first and later into the cells themselves.

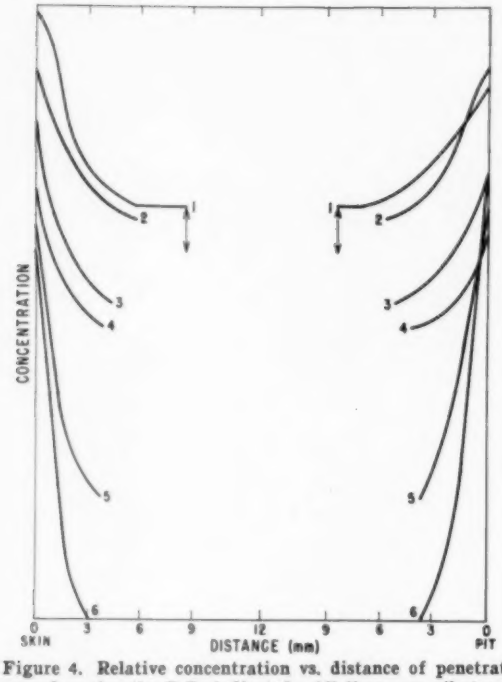

Figure 4. Relative concentration vs. distance of penetration at zero days for the D.P. indicated. All lines are offset vertically to show differences in concentration gradients. The lower tip of the arrows at D.P. 1 indicates the point of zero concentration. All other lines terminate at zero concentration.

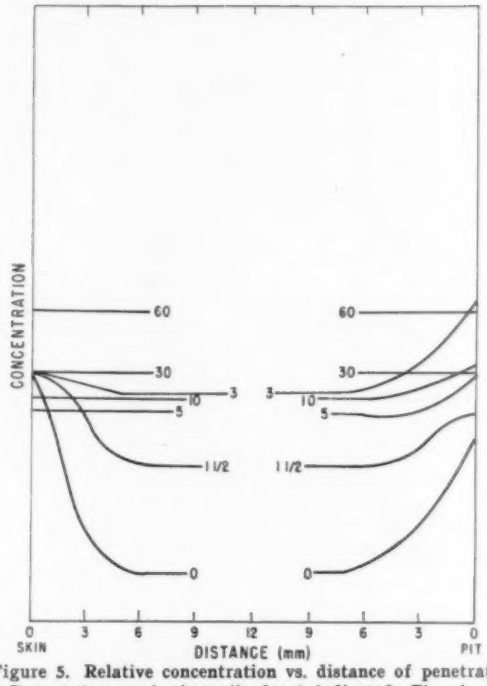

Figure 5. Relative concentration vs. distance of penetration of D.P. 1 at the sample times (in days) indicated. The abscissa of the graph is the line of zero concentration.

Sugar penetration can be considered to be a case of restricted diffusion where the peach, in mass, acts as a general restriction which slows down penetration.

The high concentration gradient of sugar, from the outside of the peach to its interior, causes an initially rapid movement of sugar into the flesh of the peach despite the rapid movement of fluid from the fruit. (The concentration gradient may be somewhat distorted due to volume changes of the peach.) The rapid movement of sugars and fluid in the zero time sample is probably accelerated because of the high temperature that was reached during cooking. This high temperature occupied about one half of the time interval on this sample. After the zero time the rate of sugar penetration decreases rapidly as the sugar concentration gradients fall.

There is a marked difference in the penetration rates of the individual sugars. The rate of penetration into the peach tissue is inversely related to the D. P. or size of the sugar molecule. The decreasing rate of penetration of the various sugars as a function of increasing D.P. probably is the result of several factors: the diffusional coefficient and concentration gradients, both of which decrease with increasing sugar size, the greater resistance offered by the peach tissue to large molecules, and the interaction effects of a multiple component system. The presence of a relatively large concentration gradient at 60 days with the D.P. 4, 5 and 6+ sugars indicates that these sugars experience some sort of obstacle to their ready diffusion.

During the course of the study, all the sugars showed only one direction of motion: from the syrup into the peach by a diffusion process. However, the fluid moved from the peach into the syrup during the first one to two days and then from syrup into the

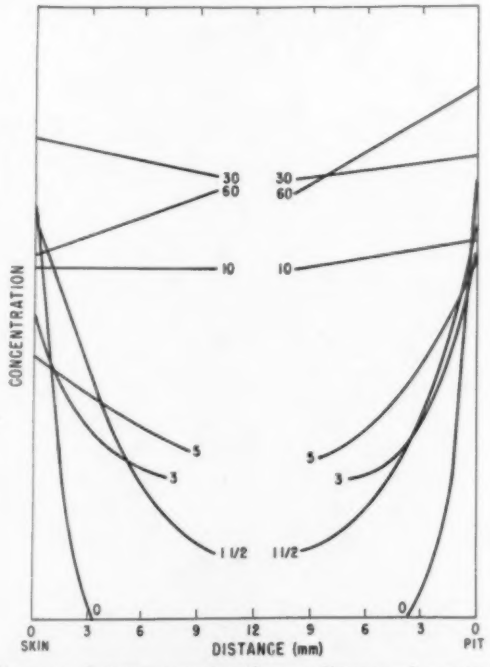

Figure 6. Relative concentration vs. distance of penetration of D.P. 6+ at the sample times (in days) indicated. The abscissa of the graph is the line of zero concentration.

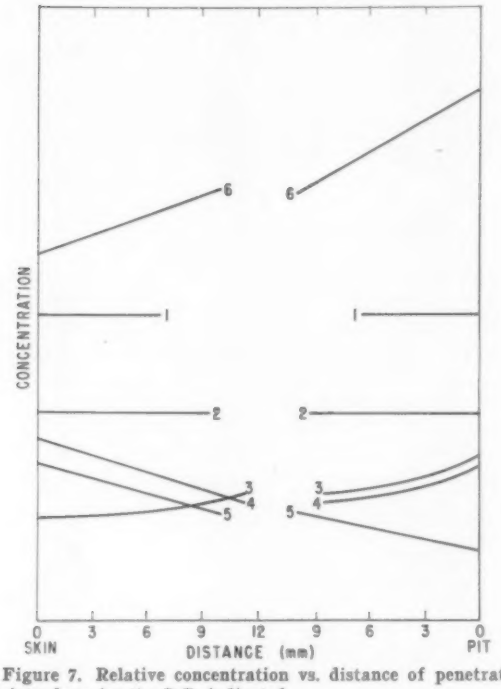

Figure 7. Relative concentration vs. distance of penetration at sixty days for the D.P. indicated.

peach. Movement of fluid from peach into syrup probably was due to osmotic pressure differences across the imperfect semipermeable membranes of the peach cells. The flow of fluid under the osmotic pressure gradient very likely continued until the activity of the water was equal in the syrup and peach. However, it seems reasonable to assume that there was still an activity gradient with respect to the individual sugar species. These would continue to move into the peach. Perhaps there was thus a lowered activity of the fluid in the peach. The fluid of the syrup could then begin to diffuse into the peach. This diffusion of sugars and fluid probably continues until the activities of all the individual molecules are equal within the syrup and the peach. The equilibrium condition was not attained during this study.

In relation to the problem of drained weight, it appears that the initial decrease in drained weight of a canned fruit is due to flow of fluid out of the fruit into the syrup. Following this initial decrease in drained weight, there is a rapid increase in drained weight. This would correspond to the rapid penetration of sugars and fluid found in this experiment. It is possible that the rate of attainment of a specific drained weight will depend upon the rate of penetration of the particular sugars from the syrup into the fruit.

SUMMARY

The penetration of maltosaccharides in processed clingstone peach halves was studied with C^{14} labeled sugars. These radioactive components in the syrup and peach were followed by histological and radiochemical techniques.

No hydrolytic breakdown of the 42 D.E. corn syrup was found to occur after processing and storage of the peaches.

The sugars, at least up to a D.P. of 6, diffuse into the cells as well as between the cells.

The rate of sugar penetration is related directly to the concentration and inversely to the D.P. of the sugar molecule.

The phenomena observed in drained weight problems can be directly related to the sugar and fluid movement observed in this study.

Acknowledgment

The authors wish to thank American Maize-Products Company for the grant which made this study possible.

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Notes and Letters

Evaluation of Canning Processes When g is Less Than 0.1

THE FORMULA METHOD of Ball *(1)* is widely used for evaluating canning processes. The Tables of functions for use with this method do not extend to values of g less than 0.1. Values of g smaller than this commonly occur in products heating by convection and Ball devised a method for dealing with such cases (Ball & Olson, p. 345). An alternative to his procedure, which is developed here, is perhaps a little simpler to use and faster. It is particularly convenient for calculating come-up time corrections in ampoules or TDT cans.

Using Ball's notation, the F value for the heating phase of a process is given by

$$F = \frac{f\,L_1}{2.3026}\,[(-Ei\,(-2.3026\,g/z)] - [Ei(-2.3026\,jI/z)] \qquad (1)$$

The second term within the square brackets is always negligible when there are no breaks in the heating curve and the first term may be expanded in series:

$$-Ei(-x) = \ln\,(1/x) - \gamma + x - \frac{x^2}{2.2!},$$

where γ is Euler's constant 0.5772. When $g < 0.1$ and z is of the order of 18° F. only the first two terms of this series need be retained. Substituting $g = jI.\,10^{-I/f}$ we have, after some rearrangement,

$$F = L_1\,[t - f(\log jI/z + 0.613)] \qquad (2)$$

In equation (2) the quantity within the braces is the equivalent time at retort temperature, expressed in the form: actual heating time less a correction term which is proportional to f. The factor L_1 ($= 10^{-(250-T_1)/z}$) converts this to the equivalent time at 250° F. The correction term in equation (2) is very easily calculated. If jI = 100° F., z = 18° F., and f = 5 min., it is 6.8 minutes.

There are several ways in which the contribution of the cooling phase might be estimated. Accepting Ball's approximation to the form of the cooling curve (Ball & Olson pp. 320ff) an estimate may be derived from his Tables of the ρ function (Ball & Olson p. 346). These extend only to g = 0.1 but it may be inferred from them that the F value of the cooling phase is less than 5–6% of that of the heating phase in cases such as those considered here.

Another simple approximation, which will often be a better estimate than that just given, may be derived from the equations given by Ball and Olson on pages 323–4 of their book *(1)*. It follows immediately that for the cooling phase,

$$F < 0.152 f L_1 e^{0.691m/z} K_1\,(0.691m/z) \qquad (3)$$

It is easily seen, by a study of the integrals involved, that the right hand side of the inequality (3) is a fair approximation to F when m/z is large (e.g. $\geqslant 6$) but not when m/z is small. Thus it will be useful in estimating the destruction of spores but may not always be an adequate approximation in estimating the destruction of thiamine or other reactions with relatively small temperature coefficients.

The function $e^u K_1(u)$ has been tabulated *(2)*. These Tables were used to calculate the values given in Table 1.

TABLE 1

Values of ϕ (m, z) = 0.152 $e^{0.691m/z} K_1$ (0.691m/z)

m/z	6	7	8	9	10
ϕ(m, z)	0.101	0.093	0.086	0.081	0.076

Thus the total F value for the process may be estimated by the relation

$$F = L_1\,[t - f(\log jI/z + 0.613 - \phi)], \qquad (4)$$

where ϕ is obtained from Table 1 and is usually approximately 0.08. This correction for the cooling phase might reasonably be neglected because it is small and is not usually known precisely. In retort operation there is generally an appreciable interval of time between cutting off steam and the immersion of cans in water at or near the nominal cooling water temperature. Variations in this interval have a significant effect on the lethal value of the cooling phase in products heating by convection but they will be of less importance in products heating by conduction.

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E. W. HICKS
Commonwealth Scientific and Industrial Research Organization, Division of Food Preservation, Homebush, N. S. W., Australia

October 8, 1957

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butic, and diphtheria-intoxicated guinea pigs. The evidence indicated that the biol. half life of ascorbic acid in the guinea pig is neither decreased in stress nor increased in scurvy. Regardless of the magnitude of the body ascorbic acid level, a definite fraction per day was lost by the animal, this predictable quantity being independent of the test conditions employed.

Occurrence of trans fatty acids in human tissue.

JOHNSTON, P. V., JOHNSON O. C. AND KUMMEROW, F. A. (Dept. of Food Technol., Univ. of Illinois, Urbana). *Science 126*, 698–9 (1957).

Autopsy and biopsy material, including adipose tissue, heart, liver and aortic tissue, from human subjects, contained 2.4–12.2% trans fatty acids in the lipid exts. The source of these acids is considered to be hydrogenated vegetable oils.

The metabolism of the essential fatty acids. VI. Distribution of unsaturated fatty acids in rats on fat-free and supplemented diets.

MEAD, J. F. (Atomic Energy Project, School of Med., Univ. of California, Los Angeles). *J. Biol. Chem. 227*, 1025–34 (1957).

By the use of a reverse-phase chromatographic method, the unsaturated fatty acids from the depot and organ fats of rats on a fat-free diet or this diet supplemented with methyl linoleate or linolenate were sepd., identified, and estd. In all 3 groups, there was a large decrease in linoleic acid and a corresponding increase in palmitoleic acid. In the linolenate-fed animals, no linolenic acid could be found, but a docosapentaenoic acid appeared. By the appearance of a typical eicosatrienoic acid and by other signs, it was apparent that, although growth had resumed in the supplemented groups, their fatty acid distribution was still typical of the state of fat deficiency.

Role of proline in polypeptide chain configuration of proteins.

SZENT-GYORGYI, A. G. (Marine Biol. Lab., Woods Hole, Mass.). *Science 126*, 697–8 (1957).

A striking correlation exists between proline content and the extent of helical configuration of proteins in the keratin-myosin-epidermin-fibrinogen class. It is suggested that less than 3% proline in the chain permits more than 50% α-helix content, 8% deforms the backbone into a random coil, and that very high proline may favor a poly-L-proline type helix. Sulfur or phosphorus cross linkages, which may interfere with α-helix formation, result in exceptions to the above.

Trypsin monolayers at the air-water interface. III. Structural postulates on inactivation.

AUGENSTINE, L. G. AND RAY, B. R. (Dept. of Chem. and Chem. Eng., Univ. of Illinois, Urbana). *J. Phys. Chem. 61*, 1385–8 (1957).

It is postulated that several phys. means of inactivating proteins have the following sequential steps in common: (1) rupture of a disulfide bond, (2) breaking of one or more other bonds, and (3) opening of a second disulfide bond which allows the destruction of many intramol. bonds and leads to a general unfolding of the molecule. It is predicted that an external pressure—a film pressure—can act to maintain mol. configuration, and therefore activity, against both surface and radiant energy effect which would disrupt the molecule. A min. film pressure should be necessary. Also, the effect of radiation should fall off at higher film pressures. In general, there is agreement between exptl. results and prediction.

Properties of the proteolytic enzymes of commercial ficin.

WHITAKER, J. R. (Dept. of Food Technol., Univ. of California, Davis). *Food Research 22*, 482–93 (1957).

When casein is used as substrate, cysteine activated ficin possesses two peaks of proteolytic activity, pH 6.72 and 9.50. The enzyme-substrate complex is believed to consist of one molecule each of ficin and casein. The rate of heat inactivation of dilute solns. of ficin did not follow first order kinetics. The heat of inactivation was calcd. to be 71,700 cal./mole. Ficin is activated by cysteine, thioglycolic acid, sodium cyanide and versene and inactivated by H_2O_2, I_2 and iodoacetic acid. A hypothesis is advanced that crude ficin is composed of two proteolytic enzymes.

Selective removal of nonprotein sulfhydryl compounds from biological systems.

BESCH, P. K., GOLDZIEHER, J. W. AND MCCORMACK, S. (Dept. of Endocrinol., Southwest Foundation for Research & Education, San Antonio, Texas). *Science 126*, 650 (1957).

Nonprotein dialyzable sulfhydryl compds. can be removed from tissue homogenates by sealing insol. *p*-CMB-resin in a small dialysis bag and immersing this bag in the homogenate. The *p*-CMB-resin is composed of sodium *p*-chloromercuribenzoate bound by its carboxyl group to Dowex 2-x resin, leaving the mercury end free.

The design of an apparatus for biological experiments at high hydrostatic pressure.

DOWNING, A. C. AND WILKIE, D. R. (Depts. of Biophys. and Physiol., Univ. College, London). *J. Scientific Instruments 34*, 353–5 (1957).

Describes simple, inexpensive design that can be used up to 1,000 atm. The stainless steel pressure chamber is provided with 6 insulated Pyrotenax leads and a permeability bridge for measuring mechanical changes. It has been used for recording the tension developed by a stimulated muscle but could be readily adapted to suit other exptl. requirements.

Microbiology

Effect of nutritional state and other conditions on ultraviolet resistance and photoreactivation in yeast.

GIESE, A. C., IVERSON, R. M. AND SANDERS, R. T. (Dept. of Biol. Sciences, Stanford Univ., Calif.). *J. Bacteriol. 74*, 271–9 (1957).

The effect of various environmental variables upon inhibition of growth of the yeast, *Saccharomyces cerevisiae*, by u. v. radiations was studied. Yeast starved for nitrogen becomes much more sensitive to u. v. than when starved for glucose alone. In the absence of oxygen yeast is about as sensitive to u. v. as in air. Irradiated yeast recovers from the u. v. injury to a considerable extent in the dark if suspended in a phosphate buffer soln. at 28° C.

Nutrition

Nutritional consideration of the older person.

KOUNTZ, W. B. (Div. of Gerontol., Washington Univ. School of Med., St. Louis, Missouri). *J. Gerontol. 12*, 433 (1957).

The older person does not have the ability to absorb and utilize fat, carbohydrate and protein as well as younger persons. It is suggested that proper diet and hormone administration will help the aged. Low levels of vitamins A, C, and D as well as trace minerals may be supplied by dietary supplementation.

Studies on the availability of Ca. V. The relation of oxalic acid, and the kind and quality of fat to Ca utilization.

IWAO, H. (Natl. Inst. Nutrition, Japan). *Japan. J. Nutrition 12*, 87–96 (1954); *Biol. Abstr. 31*, No. 27653 (1957).

The reduced absorption of Ca in rats caused by 1% oxalic acid is counteracted by feeding diets contg. 5–20% fat. The more fat fed within these limits the better the absorption of Ca. Improved absorption was observed when the fat was soybean oil, beef fat, and hydrogenated oil but not when it was herring oil.

The effect of vitamin D-deficient diets containing various Ca:P ratios on cats.

GERSHOFF, S. N., LEGG, M. A., O'CONNOR, F. J. AND HEGSTED, D. M. (Dept. of Nutrition, Harvard School of Public Health, Boston, Mass.). *J. Nutrition 63*, 79–93 (1957).

Rickets has been produced in kittens fed purified diets lacking vitamin D. More severe rickets was produced by a diet contg. 1% of Ca and 1% of P than by one contg. 2% of Ca and 0.65% of P. Cats which survive the acute rickets present during their rapid-growing period later develop a spontaneous heal-

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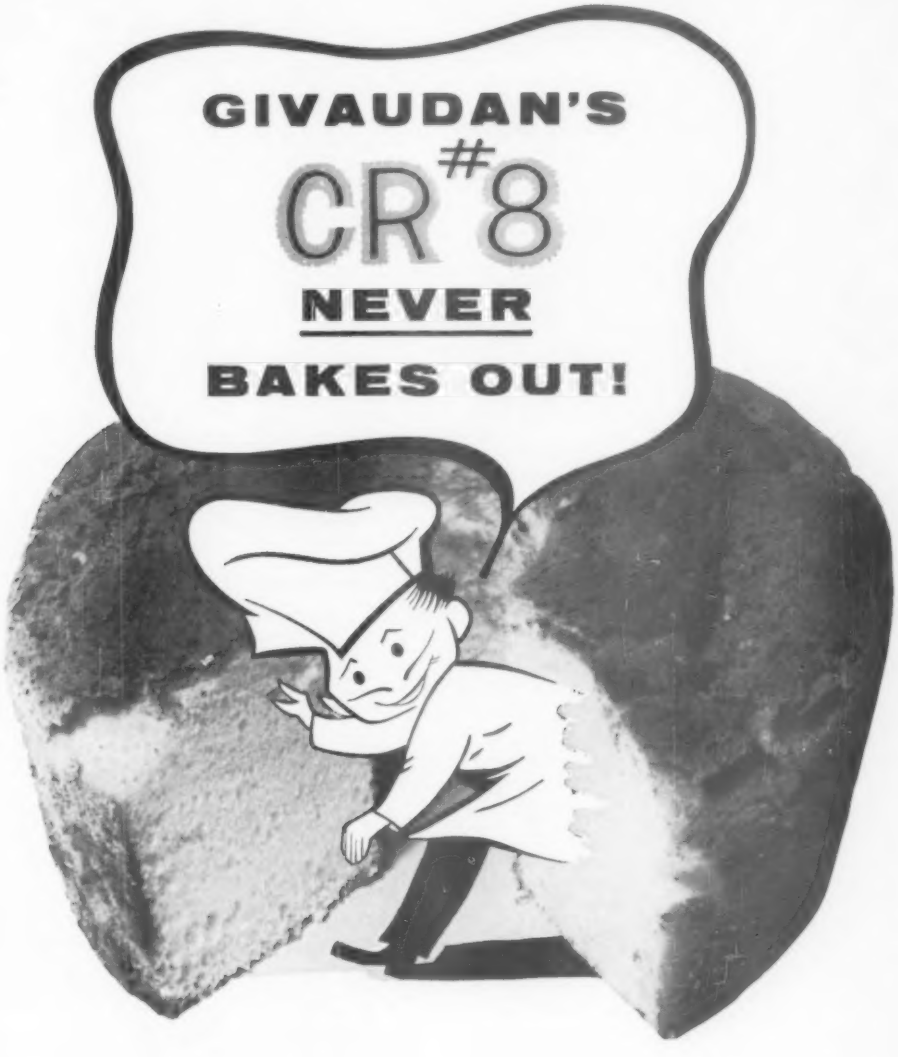

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ing of their rickets, indicating a low vitamin D requirement in young adult cats.

The rachitogenic effect of vitamin A.

GRANT, A. B. AND O'HARA, P. B. (Animal Research Stat., Dept. Agr., Wallaceville, New Zealand). *New Zealand J. Sci. and Technol. Ser. A. 38*, 548–76 (1957); *Biol. Abstr. 31*, No. 27691 (1957).

Dead brown leaves of pastures contain appreciable amts. of vitamin D whereas green leaves contain a rachitogenic factor. A rachitogenic factor was isolated from green feed and identified as carotene. The factor is more properly vitamin A since equiv. amts. of vitamin A and carotene have the same rachitogenic potency. Vitamin A probably has no direct inhibitory effect on vitamin D but appears to exert its rachitogenic influence in some other way, possibly by its local action at the site of bone formation.

The vitamin-sparing action of sorbitol.

MORGAN, T. B. AND YUDKIN, J. (Dept. of Nutrition, Queen Elizabeth Coll., Univ. of London). *Nature 180*, 543–5 (1957).

The addn. of sorbitol to thiamine-free diets of rats produced a rapid gain in wt., whereas the addn. of the same amt. of glucose resulted in polyneuritis and death. Subsequent expts. with sorbitol diets contg. no B vitamins resulted in good growth for 3 months demonstrating that the administration of sorbitol appears to make an animal independent of not only thiamine but also other vitamins of the B group.

Iron absorption and metabolism. I. Interrelationship of ascorbic acid and vitamin E.

GREENBERG, S. M., TUCKER, R. G., HEMING, A. E. AND MATHUES, J. K. (Research and Development Div., Smith, Kline and French Labs., Phila. 1, Penn.). *J. Nutrition 63*, 19–31 (1957).

The effects of supplements of Fe with ascorbic acid and vitamin E on hemoglobin regeneration were studied in milk-fed anemic rats. The rate of hemoglobin regeneration was consistently greater in rats supplemented with Fe plus ascorbic acid and vitamin E than with Fe alone or with Fe plus either of the vitamins. In a long-term study hemoglobin levels were better sustained after the cessation of Fe supplements if the Fe had been given concomitantly with ascorbic acid and vitamin E than if given alone or with either vitamin separately.

Protein factors and experimental rat caries.

BAVETTA, L. A. AND MCCLURE, F. J. (Natl. Inst. of Dental Research, Natl. Insts. of Health, Public Health Service, U. S. Dept. of Health, Education and Welfare, Bethesda, Md.). *J. Nutrition 63*, 107–17 (1957).

A cariogenic diet contg. a roller-process skimmilk powder remained highly cariogenic after supplementation with known vitamins and essential amino acids. Caries severity was significantly reduced, however, by the addn. of 11% of casein in place of cornstarch to this diet. A supplement of blood albumin proved as effective as L-lysine in the reduction of caries produced by a lysine-deficient skimmilk powder diet. Diets contg. 13% of casein developed a high incidence of severe caries but caries was very limited with 24% casein in the diet. An autoclaved mixture of casein, lactose, and Hubbell, Mendel and Wakeman salts compared with unautoclaved casein was assocd. with an increased incidence of caries when the casein content of the diet was 13% but not when it was 24%. An inhibitory effect of a lysine supplement on caries was observed using purified diets contg. zein as a source of protein. The combined results of these studies suggest that the quantity of protein in the diet may be an important factor in the development of cariogenicity by exptl. diets.

A review of the effects of different carbohydrates on vitamin and amino acid requirements.

HARPER, A. E. AND ELVEHJEM, C. A. (Dept. of Biochem., Univ. of Wisconsin, Madison). *J. Agr. Food Chem. 5*, 754–8 (1957).

The literature on the effects of different carbohydrates on vitamin and amino acid requirements has been reviewed. A substantial body of evidence indicates that when a less sol. carbohydrate is substituted in the diet for a more sol. one, the requirements for most members of the vitamin B complex and for essential amino acids, reported as a percentage of the diet, decrease. The effect of complex carbohydrates in lowering vitamin B requirements has been related to changes in the intestinal microflora; however, there is no evidence to suggest that such changes influence amino acid requirements. Instead, the lower amino acid requirements appear to be a result of physiological effects on food intake, digestion, or absorption. Thus, although dietary carbohydrate serves primarily as a source of calories, indirect effects of individual carbohydrates may be of considerable nutritional significance.

Atherosclerosis—a preventable factor of early aging.

BORTZ, W. AND LARSEN, N. P. *Geriatrics 12*, 598-602 (1957).

Very few young men will ever show a heavy deposit in their coronary arteries if they will consume only 20% or less of their calories as fat. Evidence indicates that this factor, which is controllable, will help us to defer, and possibly prevent, an unpleasant, and uncomfortable old age.

Estimation of total cholesterol in serum by a micro method.

CARPENTER, K. J., GOTSIS, A. AND HEGSTED, D. M. (Harvard School of Public Health, Boston, Mass.). *Clin. Chem. 3*, 233–8 (1957).

Describes method for estn. of total cholesterol in 0.02 ml. of serum without the need for micro app. It involves the measurement of the fluorescence developed after the addn. of H_2SO_4 to a soln. of cholesterol in a mixt. of 1,1,2-trichloroethane and acetic anhydride.

Alterations in the serum activity of some myocardial enzymes in heart disease.

LA DUE, J. S. *Geriatrics 12*, 528–34 (1957).

The increased activity of the enzymes serum glutamic oxaloacetic transaminase and serum glutamic pyruvic transaminase reflects accurately acute myocardial damage of as little as 1 g. of heart muscle.

Symposium on obesity.

GOLDSMITH, G. A. (Tulane Univ. School of Med., New Orleans, La.). *Metabolism Clin. and Exptl. 6*, 404–61 (1957).

A symposium covering historical remarks, physiologic basis of obesity, psychiatric aspects, metabolic aspects, and modern living habits and wt. control.

The handling of experimental animals as a control factor in animal research —a review.

BERNSTEIN, L. AND ELRICK, H. (Dept. of Psychol. and the Medical Research Lab., Veterans Admin. Hosp., Denver, Colo.). *Metabolism Clin. and Exptl. 6*, 479–82 (1957).

A review of the literature indicated that there might be striking changes in the albino rat as a function of handling or gentling. It was suggested that the variable of handling be made a standard procedure for both control and exptl. animals in studies in which wt. gain, skeletal length or reaction to stress is a dependent variable. It may well be that there are still other changes, previously considered to be the result of a given agent or procedure, which are due to or modified by differences in the handling of exptl. animals as compared to controls.

FOOD AND FOOD TECHNOLOGY

Antioxidants

Antioxidant activity of phenols as related to effects of substituent groups.

MILLER, G. J. AND QUACKENBUSH, F. W. (Dept. of Agr., Chem., Univ. of

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Wyoming, Laramie). *J. Am. Oil Chemists' Soc. 34*, 404–9 (1957).

Antioxidant activity in lard was exhibited by all phenols which had electron-repelling groups in the 2 and 6 positions. No activity was shown by those which had electron-attracting groups in these positions. The mechanism of antioxidant action of alkyl phenols in lard does not appear to differ from that of di- or polyphenols. A free phenolic group was shown to be essential; and spectral absorption studies after autoxidation did not reveal any evidence for a dimer of the alkyl phenol. The dimer, stilbene quinone, reported isolated from oxidized petroleum oil, disappeared quite rapidly when added to oxidizing lard.

Cereals and Grains

Chemistry of wheat.

MORAN, T. *Northwestern Miller 258*, 14–18a, Oct. 8, 1957.

Author discusses several aspects of wheat chemistry including biopyhs., nutritional milling and baking technol. Agene NCl_3 as a flour improver has been replaced largely by ClO_2. Studies on the effects of ClO_2 on flour showed (1) that it destroyed the bulk of the tocopherols including vitamin E (2) of the individual amino acids in the gluten protein, only methionine, tyrosine and cysteine showed any modification even after heavy treatment with the gas, the amts. formed being less than 0.1 p.p.m. (3) there was some peroxidation of the lipids which under appropriate conditions could lead to polymerization. No toxic derivatives were formed as a result of ClO_2 nor was there any significant reduction in the nutritionally essential acids.

Role of damaged starch in the evaluation of wheat quality.

BIRD, L. H. (Agr. Research Inst., Dept. of Agr., Wagga Wagga, New South Wales). *Nature 180*, 815 (1957).

The author recommends that test baking be used in conjunction with the wheat-meal fermentation time test, the farinograph and other techniques to show that strength is not caused by the presence of damaged starch. This manifests itself by increasing the water absorption, ordinarily regarded as desirable.

"Enriched Rice"—What it must contain.

FOOD AND DRUG ADMINISTRATION. (U. S. Dept. of Health, Education and Welfare, Washington 25, D. C.) *Rice J. 60*, 2^, 24–7, Rept., 1957.

Discusses the recent FDA standard for enrichment of milled rice. The standard allows two enrichment processes, one which makes the product "rinse resistant," the other in which the rice is coated. Under the standard, each lb. of "enriched" milled rice must contain 2.0–4.0 mg. thiamine, 1.2–2.4 mg. riboflavin, 16–32 mg. niacin and 13–26 mg. iron.

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Studies on the preparation and keeping quality of bulgar.

NEUFELD, C. H. H., WEINSTEIN, N. E. AND MECHAM, D. K. (Western Regional Research Lab., U.S.D.A., Albany 10, Calif.). *Cereal Chem. 34*, 360–70 (1957).

Bulgur of acceptable quality was prepd. from white wheats over a considerable range of conditions. With moisture contents of 41% or above, cooking at 20 p.s.i. in a steam autoclave gave a satisfactory product. As moisture contents were lowered to 37%, a trend toward less complete gelatinization was noted, but this apparently could be partially countered by increasing cooking pressures to 70 p.s.i. Bulgur samples from com. sources were stored under several different storage conditions, and then were prepd. for serving by cooking in H_2O and oil. A taste panel judged bulgur held at 90° F. to be rancid after 16 wks.' storage in cotton bags, and after 23 weeks in screw-cap jars. Additions of 0.001% of butylated hydroxytoluene or butylated hydroxyanisole to samples stored in glass jars delayed development of rancidity to about 36 wks.

Coffee and Coffee Products

The chemistry of coffee.

LOCKHART, E. E. (Scientific Director, Coffee Brewing Inst., Inc.). *Coffee and Tea Ind. 80*, 21–5, (Oct. 1957).

Part 2 in a series of 3 articles summarizing the chemistry of coffee in 3 main areas—green coffee, roasting and the beverage. Discusses constituents of roasted coffee, particularly the components of coffee aroma.

Dehydrated Foods

New developments in the freeze-drying of meat.

SMITHIES, W. R. (Defense Research Medical Lab., Toronto, Canada). *Chem. & Ind. 29*, 1008 (1957).

Dehydrated meat products prepd. by vacuum freeze-drying were superior to canned foods in many cases. In this process no shrinking occurred and the meat fibres were "frozen" in position. The product rehydrated rapidly and after cooking by conventional methods resem bled cooked fresh produce.

Fats and Oils

On the configuration of cocoa butter.

LUTTON, E. S. (Research and Devel. Dept., Proctor and Gamble Co., Cincinnati, Ohio). *J. Am. Oil Chemists' Soc. 36*, 521–2 (1957).

It is concluded from x-ray diffraction, thermal curve, and enzymatic hydrolysis that the predominant glyceride of cocoa butter is 2-oleoyl palmitoyl stearin (POS) instead of 2-palmitoyl oleoyl stearin (OPS), the configuration which has been rather generally accepted. This not only supports the idea of the formation of specific glycerides in natural fats as opposed to random fatty acid distribution but also points to some important common feature in vegetable glyceride metabolism.

Variability of linolenic and linoleic acids in soybean oil.

COLLINS, F. I. AND HOWELL, R. W. (Field Crops Research Branch, Agricultural Research Service, U. S. Dept. of Agriculture, Regional Soybean Lab., Urbana, Ill.). *J. Am. Oil Chemists' Soc. 34*, 491–3 (1957).

Using an improved spectrophotometric method, a study was made of the linolenic and linoleic acid content of soybean oils representative of different geographical areas throughout the U. S. Location composites in one geographical group varied from 5.9–8.3% in linolenic acid and from 45.3–50.4% in linoleic. Variety composites varied from 5.4–8.0% in linolenic and from 43.9–51.6% in linoleic.

Extraction of oil from olives by means of electrophoresis. I. The electrophoretic principle of the extraction of oil from the olive.

CASTORINA, S. *Olearia 10*, 79–82 (1956); *Food Sci. Abstr. 29*, No. 1335 (1957).

The method described for extracting olive oil by electrophoresis has already been patented in the main olive-growing countries of the Mediterranean, and has proved technically and economically sound. Olive pulp, and the colloidal emulsion obtained by mixing it with H_2O, are placed in a container in which are 2 porous cells full of H_2O, one contg. an anode and the other a cathode. On passing a current of about 1.25 amps. at 55 to 60 volts, at a temp. of about 20° C., the cations pass to the cathode, emulsifying agents such as proteins and pectins lose their electric charges and are pptd., and oil separates from the emulsion.

Fruits and Vegetables

An accelerated storage test for dehydrated vegetables.

GOODING, E. G. B. AND DUCKWORTH, R. B. (Dept. of Food Sci., Royal Coll. of Sci. and Technol., 1, Horselethill Rd., Glasgow). *J. Sci. Food Agr. 8*, 498–504 (1957).

When dehydrated vegetables are stored at high temps. (e.g. in the tropics) they eventually become unacceptable, in most cases because of the development of brown pigments. Testing for 'tropical' storage life is usually carried out at 37°, but preliminary tests on a no. of different dehydrated vegetables suggested that the deterioration of culinary qualities (color, flavor, and texture) occurring in a certain no. of days at 55° was approx. the same as that occurring in the same no. of months at 37°. Further expts. on dehydrated potato have confirmed that there is a close correlation between the extent of browning developed under these 2 sets of conditions.

Gelatin and Gums

Protective colloid action of gelatin.

DAVIS, P. (Kodak, Ltd. Middlesex, Engl.). *Trans. Faraday Soc. 53*, 1390–4 (1957).

The protective colloid action of gelatin towards ppts. of many substances is destroyed by the addn. of hypobromite solns. The amt. of hypobromite required has been found to be const. and independent of the substance pptd. The case of AgBr which is an exception at low bromide ion concn., is considered in greater detail. Evidence is presented suggesting that the guanidine side-chain group of arginine plays an important role in the protective colloid action of gelatin.

Milk and Milk Products

The nutritive value of milk proteins—Part II.

HENRY, K. M. (Natl. Inst. for Research in Dairying, Shinfield, Reading, Engl.). *Dairy Sci. Abstr. 19*, 691–704 (1957).

The nutritive value of milk proteins may be assessed from their amino-acid content or by biol. expts. There is good general agreement between the two methods, the correlation being closer with amino-acid analyses done after enzymic treatment than after acid hydrolyses of the proteins. Compared with an "ideal" protein, milk proteins are deficient only in the sulfur-amino acids, cystine and methionine. Milk, as a good source of lysine, is a valuable dietary supplement, particularly in mainly cereal diets. Carefully controlled heat treatment and good storage conditions cause no loss in the nutritive value of milk proteins. Damage may be caused by prolonged heating at high temps. or by storage under conditions with access to air or moisture.

PACKAGING

Simplified micro-gas analysis.

DALE, R. F. (Red Star Yeast & Products Co., Milwaukee, Wis.). *Modern Packaging 30*, 151–2 (1957).

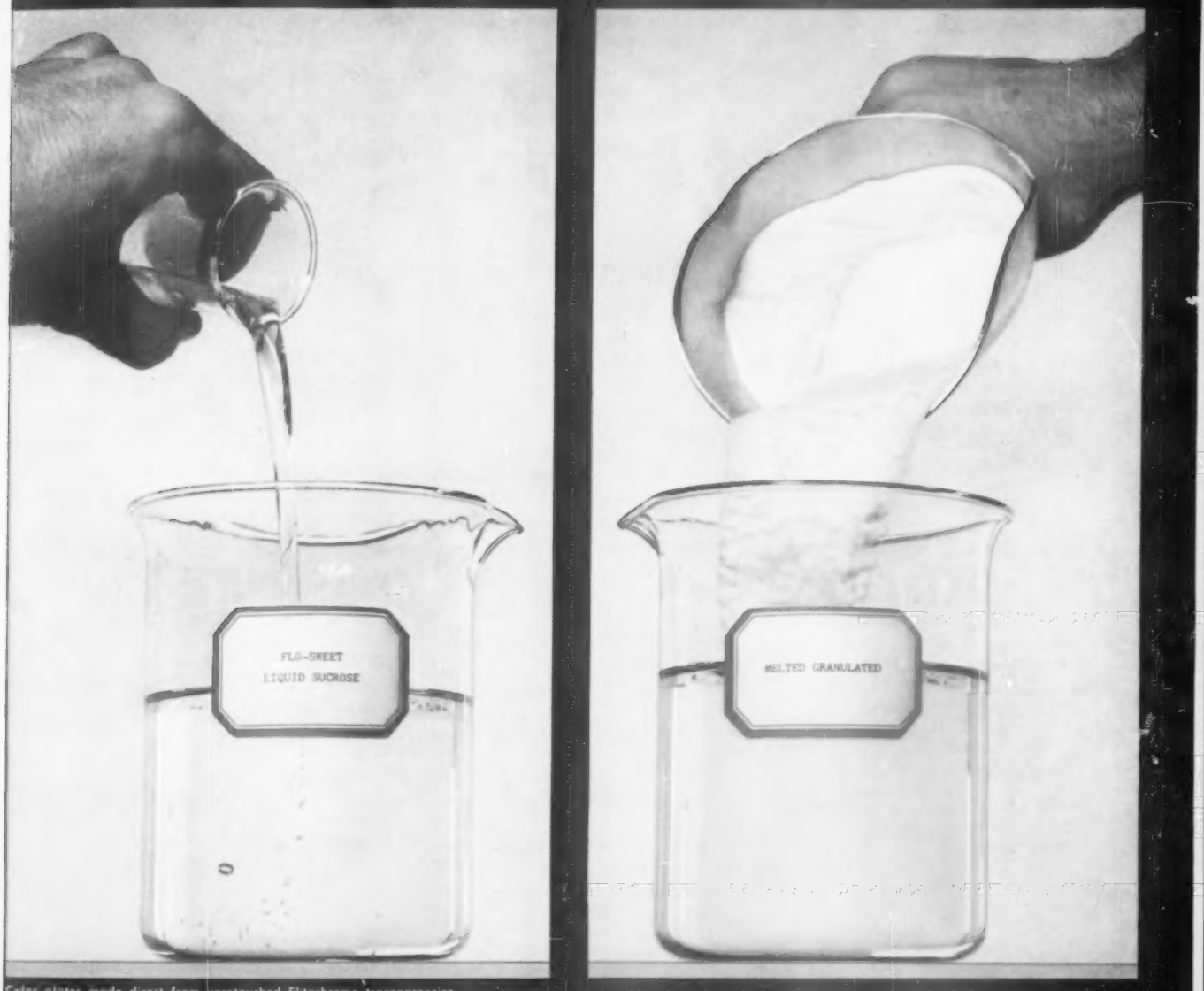
Description of a revised app., used for the detn. of the efficiency of O displacement in active dry yeast products.

PHYSICAL RESEARCH

Second international congress of surface activity.

WELLS, F. V. (Ed., Soap, Perfumery and Cosmetics). *Soap Chem. Specialties 33*, 55–9; 103–5 (1957).

Some topics discussed were: spontaneous emulsification, the dispersion of self-emulsifiable oils in aq. solns., the role of surface active agents in processes for dispersing solids in liquid media, the coagulation of oil-in-water emulsions, the energy relationships in phys. toxicity, the mol. shape, size, and adsorption in olfaction and the mol. interaction in mixed monolayers.



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RADIOCHEMICAL TECHNOLOGY

Vitamins and effects of radiation.

GLASER, E. M. AND LIVETT, R. L. *Brit. Med. J. 5031*, 1331 (1957); *J. Am. Dietet. Assoc. 33*, 938 (1957).

A large body of evidence has been accumulated which indicates that the induction of a maternal hypovitaminosis or hypervitaminosis is an effective method of producing a wide range of deformities in the rat embryo. The single deformity selected for study was anophthalmia with previous studies done to select the dose of radiation that would produce suitable standard incidence of anophthalmia. In this investigation, the administration of vitamins A, B, D, E, and ascorbic acid to pregnant rats increased to a marked extent the incidence in the young of anophthalmia induced by radiation. Absence of anophthalmic young from the control group suggests that genetic factors are not involved.

The effect of radiation sterilization on the nutritive value of foods. II. Biological value of pea and lima bean proteins.

METTA, V. C., NORTON, H. W. AND JOHNSON, B. C. (Div. of Animal Nutrition, Univ. of Illinois, Urbana). *J. Nutrition 63*, 143–54 (1957).

The effect of irradiation sterilization and of heat cooking on the nutritive value of the protein in the fresh frozen garden pea and the lima bean was studied by the Thomas-Mitchell method. A 3 million r γ irradiation was used to sterilize the frozen canned samples. No significant loss in nitrogen of the peas or beans resulted due to irradiation. Irradiation sterilization, like heat cooking, did not affect the digestibility of the raw pea protein (92%). While the biol. value of the pea protein (58%) was also not affected by short-time cooking, irradiation sterilization with 3 million r dosage reduced it by 8%. Cooking also increased the digestibility by 9% and the biol. value by 12%. On the other hand, irradiation of the raw lima beans with 3 or even 10 million r did not significantly improve the digestibility or the biol. value of their protein. No difference in the nutritive value of the lima bean protein was found when the heat-cooked beans were compared with the irradiated and subsequently cooked lima beans. This indicates no damage to the lima bean protein due to irradiation.

MISCELLANEOUS

Safety of adipic acid as compared with citric and tartaric acid.

HORN, H. J., HOLLAND, E. G. AND HAZLETON, L. W. (Hazleton Labs., Falls Church, Va.). *J. Agr. Food Chem. 5*, 759–62 (1957).

Increased usage of adipic acid as a food additive has prompted the comparison of it with citric and tartaric acids. Acute and chronic administration to lab. animals has shown that adipic acid is comparable to these acids and is a safe food additive.

INDUSTRY PUBLICATIONS

Gas Atmospheres, Inc., has just published a bulletin describing a new **self-contained, packaged nitrogen generator.** The bulletin contains illustrations of typical installations and a description of a new one-station control panel. Charts of the overall dimensions, weights of all standard sizes and operating costs are included. Copies may be obtained by writing Gas Atmospheres, Inc., 20011 W. Lake Rd., Cleveland, Ohio.

A **laboratory weight catalog** and handbook has been released by Henry Troemner, Inc., 22nd and Master Sts., Philadelphia 21, Pa. The booklet reviews construction and tolerance details for laboratory weights, including micro, semimicro and general purpose weights.

Features and specifications of six Geyer **automatic filling machines,** for semi-liquids and semi-solids, are given in a new folder released by the Filler Machine Co., Inc., 100 Penn Ave., Rockledge, Philadelphia 11, Pa. The folder, Form fa-58, also briefly outlines the manually operated and semi-automatic fillers and auxiliary equipment manufactured by the company.

Performance and specification data for series 3000 **ring balance meters** and available accessories has been released in a new bulletin by Hagan Chemicals & Controls, Inc., 323 Fourth Ave., Pittsburgh, Pa.

Buletin PM 10002, the company states, is the most comprehensive it has produced on the single ring meter series. It contains descriptive text, tables and illustrations on accessories such as integrators, pneumatic transmitters, and pressure and temperature elements.

A new technical bulletin describing the **Thermotest portable potentiometer** for measuring temperatures and voltage, is now available. Bulletin T-57 lists 18 main uses for the instrument in the laboratory and plant and features data on special features, scales and calibrations, circuit, and condensed specifications. Technique Associates, Inc., P. O. Box 91, Indianapolis 6, Ind.

Principle and operation of magnetic flowmeters is discussed in a new Fischer & Porter catalog 10D1416. Bulletin gives advantages and specifications of F&P unit. For a copy, write Fischer & Porter Co., 461 Jacksonville Rd., Hatboro, Pa.

A technical bulletin, just relesed, presents the features, properties and characteristics of Mono-Seal **plastic-type protective coating** recently developed by Mono-Seal Products.

Mono-Seal is described as a balanced chemo-setting synthetic resin coating. Specific applications in industrial operations include fluid milk storage tanks, milk filling machines, refrigerator trucks, bottle and case washers, interior walls and ceilings and floors in processing rooms, pasteurizing vats, homogenizers, cream separators, butter churns and HTST pasteurizers. The bulletin is available by writing Mono-Seal Products, 44 Garden St., Everett 49, Mass.

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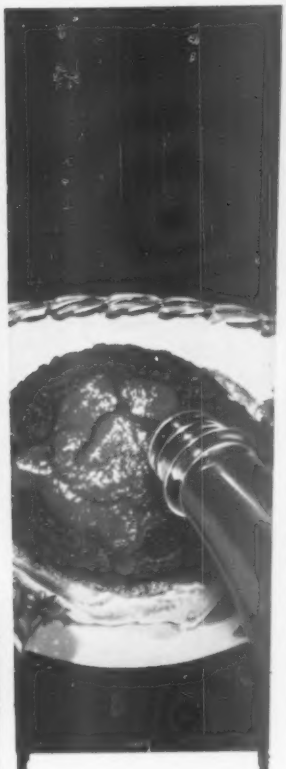

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A new **"Atlas Food Color Guide"** which contains revised information regarding permissible certified food colors and data on their solubility and stability in various liquids has been released by H. Kohnstamm & Co., Inc. Tables showing recommended usage levels as well as new blending information for the production of a range of shades have been included. Copies may be obtained by writing any of the company's branches.

A **price list of essential oils,** aromatic chemicals and certified colors has just been published by Dodge & Olcott, Inc. The 36-page book is dated October, 1957 and includes prices, descriptions and instructions for use. More than 1,500 items are listed. Copies may be obtained from Dodge & Olcott, Inc., 180 Varick St., New York 14, N. Y.

The **1958 Dow Corning Reference Guide,** which describes over 150 commercially available silicone products including those introduced within the past year, is now available. It contains charts, tables, graphs and data on properties and performance, along with illustrated examples on use and design. Catalog is coded No. 1-113, Dow Corning Corp., Midland, Mich.

A manual covering the **operation of filling containers with liquid or viscous products** is available from the Hope Machine Co., 9400 State Rd., Dept. 19S, Philadelphia 14, Pa. The manual describes two line filling machines, Type 19S. The booklet contains 16 exploded-view drawings, detailed operating instructions, and points on maintenance.

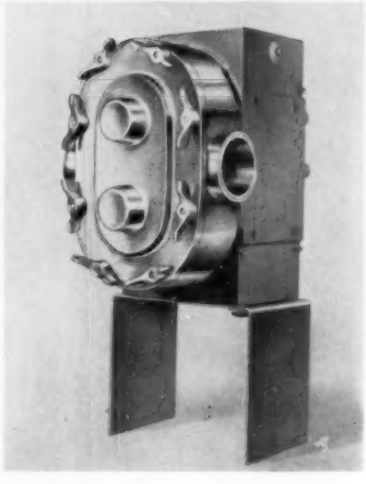
A 12-page booklet entiled **"Powdered Activated Nuchar for Purification and Reclamation,"** has recently been published by Industrial Chemical Sales division of West Virginia Pulp and Paper Co. The booklet offers hints on the use of Nuchar for the removal of impurities and objectionable taste and odors, as well as telling of Nuchar's ability to absorb desirable materials which are to be recovered.

Rod-and-tube type steam thermostats for use in commercial appliances are described in a new four-page bulletin published by Robertshaw-Fulton Controls Co., Youngstown, Pa. The bulletin describes the Model "SC" and "ST" thermostats for controlling coffee urns, dish washers, sterilizers, steam tables and similar equipment. Specifications and cut-away installation diagrams are illustrated.

A new line of Flex-O-Matic **hermatic condensing units,** featuring interchangeable compressor and condenser sections, has been developed by the York Corp., a subsidiary of Borg-Warner. The units are used for refrigeration purposes by supermarkets, restaurants, candy stores, and others. Nine models, from one-third to seven and one-half horsepower, are available.

The 1958 Arco Income Tax Guide by S. Jay Lasser, C.P.A. is now available for aiding in filling out 1957 tax returns. The guide is the fourth and latest issue of a tax manual which has been in use for some time. It deals specifically with laws applicable to this year's taxes. Copies are $1 each from Arco Publishing Co., 480 Lexington Ave., New York 17, N.Y.

EQUIPMENT



A sanitary food processing pump with a "universal mount" has been developed by Thermovac, Inc., 816 E. Hazelton Ave., Stockton, Calif. The pump is said to be corrosion resistant and a positive displacement model, No. 125TP, which is three inches in size.

The company stated that its distinguishing feature is the integral mounting assembly, which allows it to be mounted in any position relative to product lines, with original mounting provisions. No special base assemblies are said to be needed, and the "TP" pump may be mounted with drive shaft up or down, or it may be side mounted. It is made to specifications for the company by the Waukesha Foundry Co., and the mechanism is identical to the current Waukesha Pump No. 125 DO.

A machine for **filling frozen food cartons** at speeds up to 240 c.p.m. (retail size), and 110 c.p.m. (institutional size) has been announced by Food Machinery and Chemical Corporation's Canning Machinery Division. Known as the FMC No. 16S Carton Filler, or No. 8s for institutional packs, the machine employs a straight-line feed that curves slightly at the filling station to permit time for the premeasured product to enter the carton. A transfer disc is not used.

PROVERB PRATTLE

"A thing of beauty is a joy forever"

This lovely line first appears in John Keats' poem, "Endymion" written early in the nineteenth century. The full quotation is:

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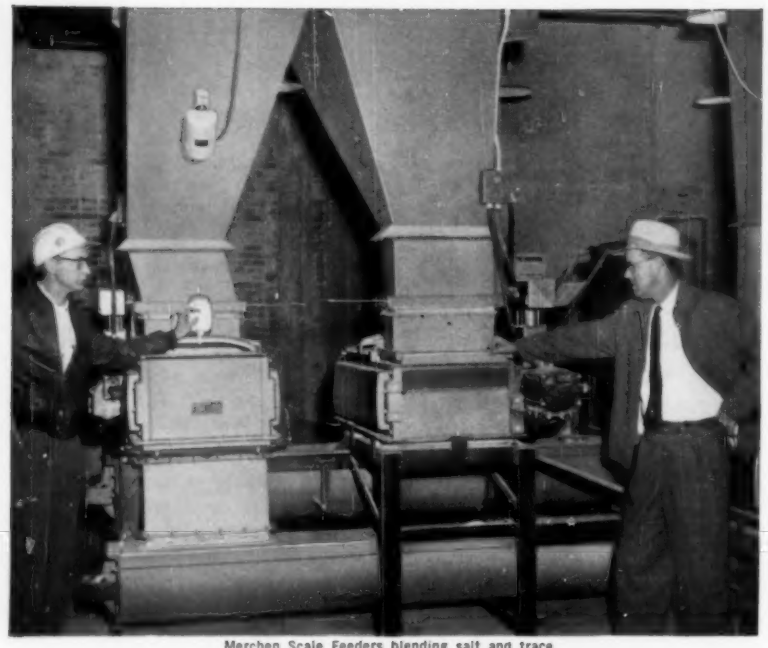

Merchen Scale Feeders blending salt and trace minerals at Carey Salt Co., Hutchinson, Kansas.

MERCHEN SCALE FEEDERS

offer continuous dry blending by weight

The Carey Salt Company produces salt blocks for cattle that contain a percent blend by weight of nutritional minerals. W&T Merchen Scale Feeders were selected for the blending operation.

If accurate blending of dry, free flowing materials is important to your production, Merchen Scale Feeders offer feed rates from 3 ounces to 3000 pounds per minute, always maintaining accuracy within 1% of the feed rate. The feeders compensate for changes in material density to maintain a constant feed by weight.

Where a number of ingredients must be blended, Merchen Feeders can be electrically or pneumatically controlled from other plant equipment for automatic operation. Send for our free booklet M-33, "The Best Weigh is the Merchen Way."

WALLACE & TIERNAN INCORPORATED

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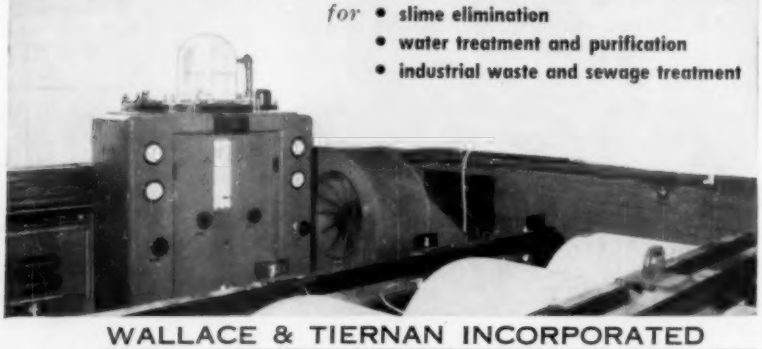
CHLORINATORS and CHEMICAL FEEDERS

for
- slime elimination
- water treatment and purification
- industrial waste and sewage treatment



WALLACE & TIERNAN INCORPORATED

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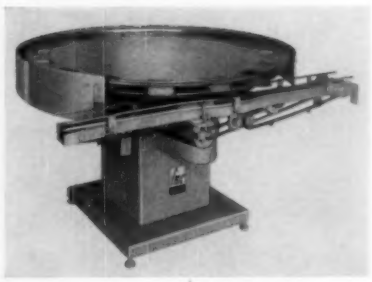

Cartons are carried in a straight line by means of a lug-chain conveyor that is synchronized with the pocket spacings of the filler. One of the main features is a "No carton-no fill" device which prevents discharge of the product from the machine unless a carton is properly positioned under the pocket. This new carton filler will be displayed at the 1958 National Canners' Show in Atlantic City, N. J. and also at the National Association of Frozen Food Packers' Show in Chicago in March.

MEMORANDA

The Institute of American Poultry Industries has established two awards which will be given to stimulate and reward research in the field of poultry and egg processing and marketing, according to an announcement made by Dr. Cliff D. Carpenter, IAPI president. Beginning in 1958, an IAPI award of $1,000.00 will be presented by the Institute of Food Technologists on a biannual basis. In 1959, and in each alternate year to follow, an award of $1,000.00 will be presented by Poultry Science Association. "It is the desire of our board of directors," said Dr. Carpenter, "to recognize outstanding research done in poultry and egg processing and marketing, which will contribute to increased consumption of our products."

Nominations for the 1958 award to be presented by IFT may be made by any member of IFT or any regional section of IFT, or by any member of the Institute of American Poultry Industries. A letter giving a biographical sketch and indicating the contributions

that quality the nominee for the award should be sent to IFT's chairman of the awards jury, Dr. C. H. Koonz, Swift & Company, Union Stock Yards, Chicago 9, Illinois. The nomination letters shall be limited to two, single-spaced typewritten sheets and are due before January 30, 1958. The presentation of the Institute of Food Technologists' award will be made during the annual meeting of IFT scheduled May 25–29, 1958.

American and Canadian companies increased the compensation paid to top executives by an average of 5.1% last year, according to the eighth annual survey of top management compensation just distributed by the American Management Association.

This compares with a 5.9 increase recorded for the previous year. These figures represent an over-all average and do not reflect the variations in individual companies and industries. Company size, complexity of operations and sales and profits are factors involved.

According to the Du Pont Co., use of an artificial sweetening agent, sodium cyclamate, in curing bacon has been cleared by the Meat Inspection Division of the U. S. Department of Agriculture. Memorandum No. 249 by the department states that sodium cyclamate may be added to bacon in an amount not to exceed 0.15 per cent.

It also specifies that slab and sliced bacon cured with sodium cyclamate should be marked with a statement such as "sodium cyclamate an artificial sweetener added."

The Du Pont company plans to offer products together with licenses for this use to the meat industry under pending patent applications.

A three-day educational forum on instrumentation in the food industries has been scheduled for April 7, 8, and 9, at the Foxboro

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With RHOZYME Diastatic Enzymes you can solubilize, saccharify, or modify food starches without sacrificing other properties vital to good products and good processing. For, RHOZYME Diastatic Enzymes assure specific, controlled action without undesirable side reactions.

Many users have found that the RHOZYME family's selective action, as well as its low cost, makes it an effective, economical answer to such processing problems as:

Processing of Pre-Cooked Cereals —by permitting higher-solids processing without raising viscosity and thereby increasing plant output.

Production of Corn Sirup — by saccharifying corn starch to make sweet, non-bitter sirups.

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ROHM & HAAS COMPANY

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Co., Foxboro, Mass. This is the fourth annual program of its kind.

The main purpose of the forum is to analyze and discuss the instrumentation available for measurement and control of variables in food processing. Attendance is limited to food men who are primarily concerned with profitable use of instruments. No charge is made for the three-day sessions, and applications should be made to W. S. Young, manager, Food Industries Division, The Foxboro Co., Foxboro, Mass.

The aims of National Library Week have been set forth by Marchette Chute of the National Book Committee. The first emphasis of Library Week, says Chute, will be on the libraries of the United States, to make our fortunate citizens realize the value of this vast, free treasure that is spread out over the land, and to help them learn how to use it at full capacity. But from this beginning the activities of Library Week will reach out in many directions. It will focus attention on the vital importance of the school library, the college library, the home library. The dates are March 16–22, 1958. Library Week will cooperate with those other great sources of enlightenment and entertainment, the magazines and newspapers of the United States, and it will work also through the national and local networks of radio and television. As the horizons of Americans are broadened there will be larger and more intelligent audiences for the theatre, films, music and everything else that is related to printed materials or reflected by them. And since the habit of reading is the best kind of adult education, it will take some of the strain off the school system and guarantee an education that will not stop when the college years are over but continue for life.

All this is the goal of Library Week. Its success will lie in the hands of the men and women who want to awaken their fellow citizens to the delight, the value and the magnificent opportunities of the habit of reading, and who will encourage them, in the first concerted national effort that has ever been made in this field, to "Wake Up and Read!"

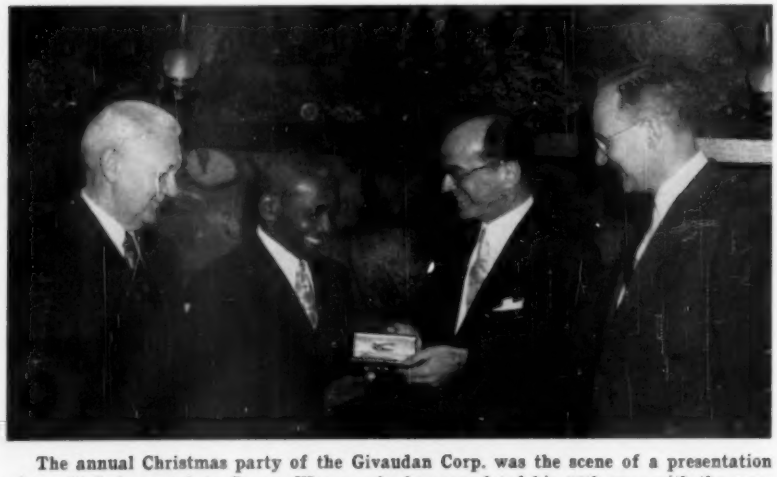
PERSONNEL

Dr. Harry E. Goresline, Associate Scientific Director of the Quartermaster Food and Container Institute for the Armed Forces, recently was awarded a 1957 National Civil Service league merit citation. Dr. Goresline entered civil service in 1930 as an associate bacteriologist. During World War II he was chief food technologist in the Department of Agriculture. Last year Dr. Goresline received the research achievement award given in recognition of his outstanding scientific contributions to the advancement of poultry and egg technology.

Benjamin d'Ancona has been named senior vice-president of the American organization of Polak and Schwartz, Inc. Mr. d'Ancona's association with the company dates back 38 years, and since that time he has held responsible positions with branches in different parts of the world before joining the United States company in 1940.

At the same time Polak & Schwartz announced that **Robert O'Hare** is now on the mid-western sales staff with offices in Chicago. His previous affiliations have been with General Beauty Products and Revlon, Inc.

Emil Hilbert has recently been named to the Durkee Bakery Technical Service staff of the Durkee Famous Foods Division of the Glidden Co. Mr. Hilbert's appointment augments the staff of technicians serving the baking industry. Mr. Hilbert has operated a bakery in Chicago for the past 12 years and has conducted demonstrations before national and local groups and has an industry-wide reputation as an expert in the art of pastry decorations. He has a master's degree from Karlsruhe, Germany, is past president of the Chicago Master Bakers Club and is cureritly serving as editor of the Chicago Retail Baker Magazine and secretary of the Associated Retail Bakers of Greater Chicago.

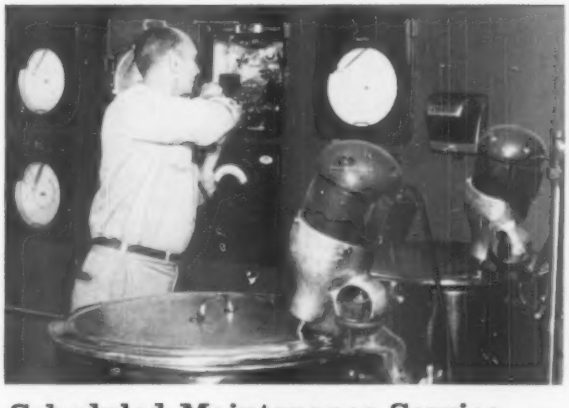


The annual Christmas party of the Givaudan Corp. was the scene of a presentation of a gold Swiss watch to George Wason, who has completed his 25th year with the company. His completion of a quarter-century of service brought the membership in the company's veteran group to 66. In the picture, left to right, are H. F. Duffy, treasurer; Mr. Wason; E. R. Durrer, president; and Dr. Max Luthy, vice-president.

Why you get
MORE FOR YOUR MONEY
with Foxboro Instrumentation

The widespread preference of leading food processors for Foxboro Instruments is no accident. Behind all Foxboro products stand 49 years of engineering integrity in creating instrumentation, not merely as mechanical devices, but primarily as the means *to make processes operate more efficiently*. You get the benefits of this experience in exclusive Foxboro Services that insure better *applications* of instruments, more dependable *performance* of your installation, and *upgrading* of your own process control men. Typical Foxboro extra-value Services:

Application Engineering — Before any application of a Foxboro Instrument or System is recommended, it has been exhaustively group-studied by Foxboro Engineers with specialized knowledge of specific industry requirements and characteristics of the process involved. Resulting Application Engineering Data is available on request.



Scheduled Maintenance Service — For your protection against variations in production quality and process down-time, Foxboro makes available a Scheduled Service Agreement. Under this plan, a factory-trained Foxboro Technician calls at scheduled intervals to maintain your Foxboro Instrumentation at continuous peak efficiency.

Training Classes — For instrument men and engineers of Foxboro Instrument users, the Company offers intensive 3-week training courses in the use, mechanics, application and maintenance of instruments. Conducted by full-time staff, with lectures by engineering and research department specialists, in Training Center at Foxboro, Mass.

WRITE FOR detailed information on Foxboro Instrumentation and its application for your "problem processes". **The Foxboro Company, 352 Norfolk St., Foxboro, Mass., U. S. A.**

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INSTRUMENTATION for the Food Industry

Ridiculous, you say. Delay can't *kill* anyone. It isn't a disease.

Yet last year, of the 250,000 Americans who were cancer's victims, 75,000 died *needlessly*. 75,000!... the populations of cities like Charleston, Santa Monica, or Racine. They might have been saved... but they put off seeing their doctors until it was too late. Their story is told in our dramatic film "The Other City"... a film which can save thousands of lives. Perhaps your own.

It teaches you the seven danger signals by which early cancer often reveals itself, and emphasizes your need for an annual health checkup as your best insurance against cancer.

"The Other City" is available, without charge, for showing at your church, your club, your community center, plant or office.

To arrange to see this and other life-saving films, made possible by your contributions, call the Unit of the American Cancer Society in your community or write to "Cancer" in care of your local post office.

AMERICAN CANCER SOCIETY

Arthur T. Schramm, a member of IFT, has been named resident manager of the New York branch of National Aniline Division, Allied Chemical & Dye Corp. Mr. Schramm's appointment became effective January 1. He succeeds Charles C. Knights who has retired after 40 years' service with the company. Mr. Schramm was previously manager of Certified Colors for National Aniline since 1956. He will continue to represent the company in matters involving the Food and Drug Administration and will serve as company representative on the Certified Color Industry Committee.

Besides being a member of the Institute of Food Technologists, he is also a member of the American Chemical Society, the American Association for the Advancement of Science and other societies.

Wesley H. Childs, formerly chief chemist of the Division of Foods, Dairies and Standards, Department of Agriculture, State of Illinois, has joined the Knechtel Laboratories in Chicago as director of research. Mr. Childs, an IFT member, has spent many years in the confectionery industry. He has served as chemist in charge of control and development of food products for Beech-Nut Packing Co., chief chemist for Nutrine Candy Co., chief chemist for Oelerich & Berry, and technical editor of The Manufacturing Confectioner. He is the author of numerous articles on candy and candy ingredients and the book, "How to Salvage Scrap Candy."

Merck, Sharp & Dohme of Rahway, New Jersey have announced that **Dr. Fred Tausig,** an IFT member has recently joined the staff of their Research Laboratories as Senior Chemist in Natural Products Development. Dr. Tausig was formerly with the Quartermaster Food & Container Institute in Chicago where he was connected with the Chemistry and Microbiology branch of the Food Laboratories. Dr. Tausig did his undergraduate work at the University of Technology, Vienna. His Ph.D. in Organic Chemistry was attained at the University of Pittsburgh.

IFT Member, **Maurice V. Kates** has announced the formation of Triple V Chemicals, 64 Glenwood Street, Malden, Massachusetts. Triple V Chemicals will merchandise a complementary line of products for the food, cosmetic, pharmaceutical and allied industries in New England and New York. The company will also offer technical services in problems pertaining to nutritional formulations, solubility, consistency, viscosity, volatility, emulsification, wetting, foaming, etc.

An Assistant Research Professor of food technology and an Extension Food Engineer joined the College of Agriculture staff at the University of Massachusetts on January 1, according to announcement made by Dean Dale H. Sieling. Dr. Hamed M. El-Bisi, formerly of the University of Illinois, will have responsibilities for the research program formerly conducted by Dr. William B. Esselen, who was recently promoted to head of the food technology department. Gerald A. Fitzgerald, a graduate of the Massachusetts Institute of Technology in 1923, is the new Extension food engineer in the department of agricultural engineering. His main area of responsibility will be in marketing education work with retail firms as one of a four-man interdepartmental team.

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Neither form affects the taste of the drink. Write for technical information on CRYSTALETS—Type W and Type M.

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Also try it for making extra smooth ice cream. Pfizer offers a variety of forms: Sodium Citrate Anhydrous, U.S.P., VIII, and Monosodium Citrate.

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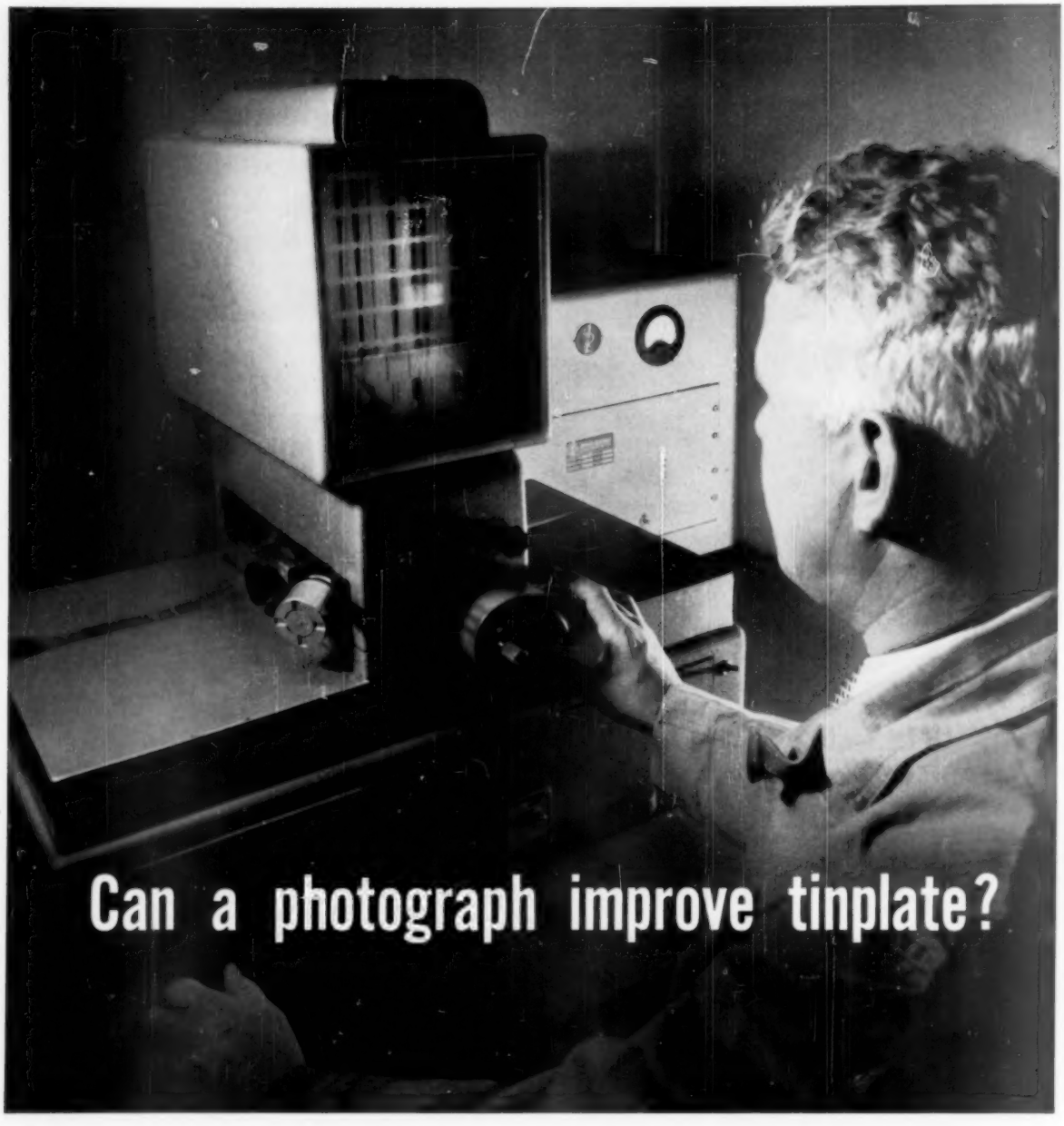

Yes . . . or at least the story told by a photograph can. The instrument you see is a densitometer—a sensitive and important piece of testing equipment. Its assignment is to help interpret photographs (taken with a light spectograph) of spectra that result from vaporizing metal samples in an emission spectograph.

Each element in the metal tested is represented by a perpendicular line on a film which is projected on the densitometer's screen. The intensity of each spectral line indicates the quantity of each element present.

By projecting the findings of these careful research steps into the actual making of steel, U. S. Steel is able to control these elements closely and thus produce the best obtainable steel strip for the manufacture of quality tinplate. Fine quality tinplate means more perfect protection for your products.

The constant efforts of scientists, chemists, engineers and technicians in U. S. Steel's Applied Research Laboratory have contributed much to the opening of entirely new fields of products that may be preserved, protected and marketed in tin cans.

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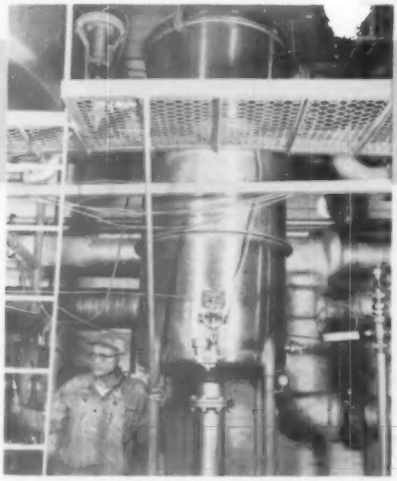
Dissolved and Entrapped Air---*Out*

Color,
Flavor,
Aroma ---------- *In*

with an FMC Deaerator

FMC Deaeration has proved to be an essential step in the processing of many types of foods. Products containing dissolved air, or that tend to entrap air bubbles or foam excessively, are subject to the harmful effects of oxidation within the container unless this air is efficiently and thoroughly removed. Employing a positive control of product flow, temperature and vacuum, the FMC Deaerator expells this detrimental air from the product resulting in a significant improvement in quality and appearance of such foods as tomato, grape, apple and orange juices, tomato catsup, table syrups and baby foods. Vitamins are preserved, discoloration is avoided and container corrosion is retarded. There are models and sizes for capacities of 2 to 100 gpm. For additional information simply call your nearest FMC representative.



At F. M. Ball and Co.'s Oakland, Calif. plant, two FMC Deaerators provide uniform, sanitary control in the processing of peach and apricot nectar and a variety of tomato products.

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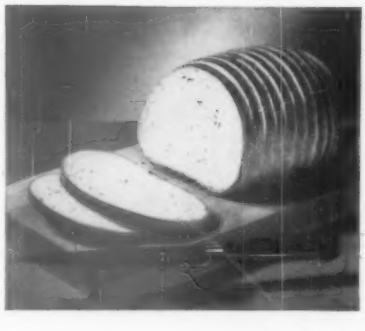

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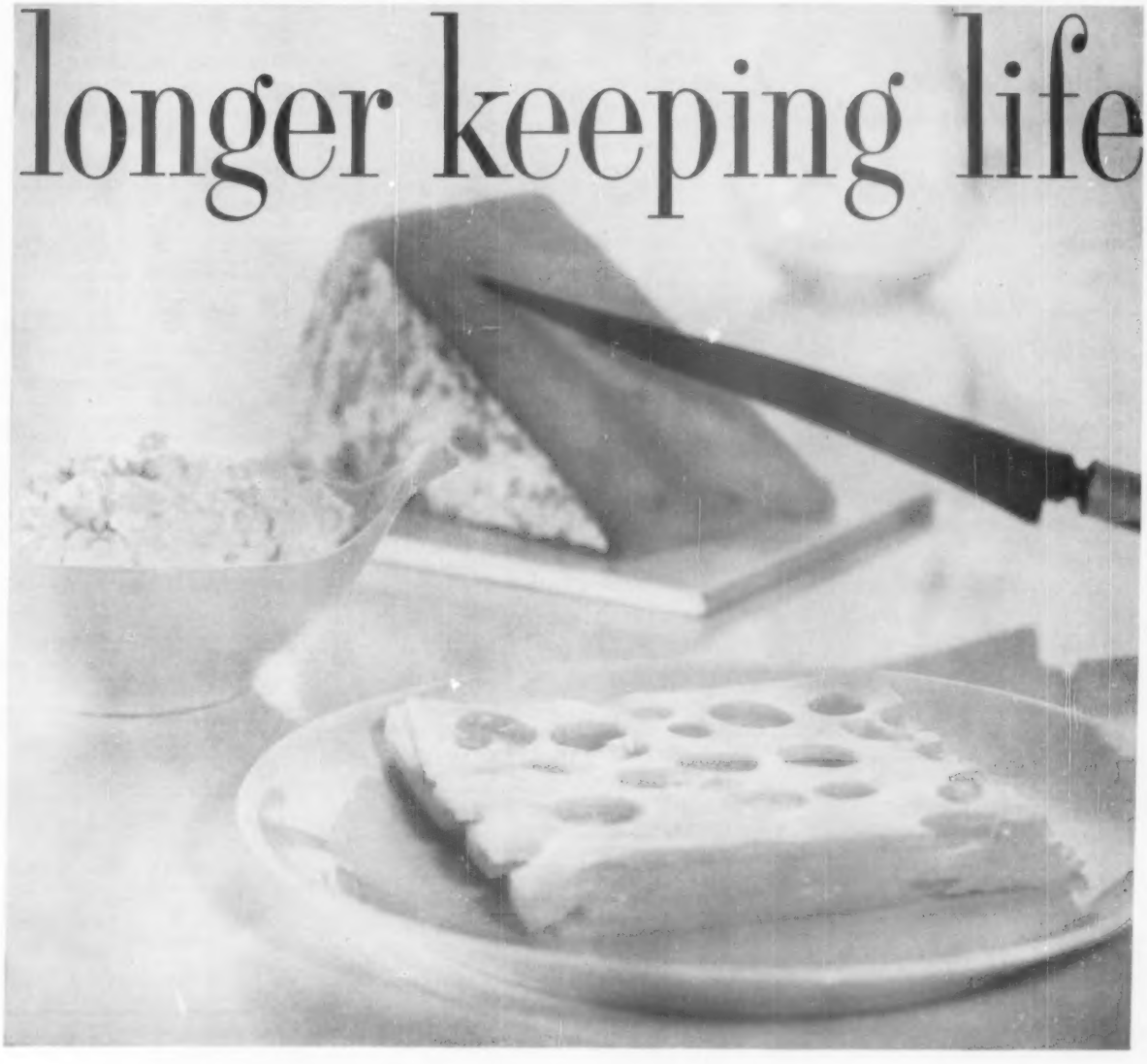

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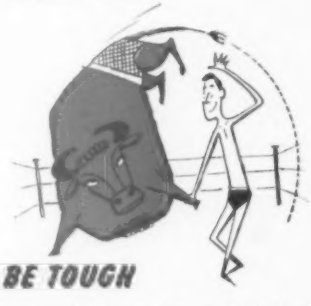

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